AGRICULTURAL ECONOMICS RESEARCH

A JOURNAL OF THE
U.S. DEPARTMENT OF AGRICULTURE
ECONOMIC RESEARCH SERVICE

JANUARY 1977 VOL. 29 NO. 1

$$\frac{1}{1-b} \doteq 1+b$$

$$\doteq 1+b+b^2$$

$$\doteq 1+b+b^2+b^3$$

$$\doteq 1+b+b^2+b^3+b^4$$

$$\doteq 1+b+b^2+b^3+b^4 \ldots + b^n \ldots$$

Price Multipliers - page 1

AGRICULTURAL ECONOMICS RESEARCH

JANUARY 1977 VOL. 29 No. 1

A Journal of Economic and Statistical Research in the United States Department of Agriculture and Cooperating Agencies

Contents *Page*

THE EFFECTS OF REAL MULTIPLIER VERSUS RELATIVE PRICE CHANGES ON OUTPUT AND INCOME GENERATION IN INPUT-OUTPUT MODELS

By Gene K. Lee and Gerald E. Schluter*

When using input-output analysis to measure the effect of exogenous changes in the value of final demand, it is important to identify the degree to which the change in value is due to changes in prices or to changes in the volume of demand. A modified input-output model is presented to incorporate changes in prices as well as changes in the volume of final demand. The empirical results demonstrate that changes in the volume of final demand stimulate output and income directly, while changes in price have no effect on output but do influence income levels.
Keywords: Input-output, impact analysis, inflation.

INTRODUCTION

Input-output (I/O) analysis has become an increasingly popular tool of economic researchers. This popularity is well founded because I/O allows the researcher to explicitly consider complex economic interrelationships in modern economic systems. Unfortunately, one of the hazards of popularity of a research technique is a tendency to lose sight of its limitations and underlying assumptions.

In this article we emphasize the role of the underlying assumption of constant relative prices in I/O analysis and the effect of relaxing this assumption. Because it takes a relatively long period of time (often 5 years) to assemble the data for an input-output table, the price assumption may no longer be realistic by the time the table is available for empirical analysis.[1] Yet because the matrix of output multipliers, $(I-A)^{-1}$, reflects the output effects of changes in final demand expressed in value terms, it is important to know if these observed changes are due to changes in price, changes in volume, or some combination of both. In recent experience, differential inflation rates have contributed substantially to increases in the values of various final demand sectors. Though they are empirically difficult to separate, conceptually it is important to distinguish the effects of relative price changes from the "real" multiplier effects on the economy resulting from volume changes.

Realistically, constant relative prices form a questionable assumption because, as the price of one sector increases, other prices neither increase simultaneously nor proportionately.[2] Because their returns are established as a residual after all variable costs have been paid, revenues for certain sectors of the economy will rise faster than costs. Hence, income generation depends not only upon the structure of the economy but also upon the importance, as intermediate inputs, of the commodities whose prices have changed.

Although not allowed for in I/O analysis, differential rates of inflation could result in the price-induced substitution between different intermediate inputs and primary inputs, such as labor. This substitution would change the input mix in an industry's production function; that is, change the direct input-output technical coefficients and, hence, cause structural changes in the economy (another violation of a basic I/O assumption). This result, however, occurs only after enough time has passed to allow for the substitution.[3] For many sectors of the economy, once a production process is adopted, production patterns will be quite fixed and stable, with no substitutions.[4]

The significant changes in recent relative prices suggest that a re-examination of the use of input-output

*The authors are agricultural economists with the National Economic Analysis Division, ERS.

[1] For example, the 82-sector version of the U.S. input-output table for 1967 was published in February 1974, and the 1972 table will probably not be available until late 1977 or early 1978. During this period (1967-74), the 3-digit code wholesale price indices went as high as 371.8 (1967=100) for coal (#091) and as low as 94.1for home electric equipment (#125) (*9*). Italicized numbers in parentheses refer to items in References at the end of this article.

[2] Disproportionate changes in all prices contribute to general inflation as affected sectors adjust price and output to new price conditions, a situation we have experienced recently. Because of these different rates of change in prices, economists such as Milton Friedman propose "indexation" to achieve stable purchasing power (or relative price constancy) (*3*, pp. 174-176).

[3] Analysts in the Bureau of Economic Analysis, U.S. Department of Commerce found that, when cross sectional analysis was applied to determine if any significant price-induced substitution effects occurred between 1947 and 1958, very few such substitutions took place among intermediate inputs alone, but substantial substitution occurred between intermediate inputs and value added. They also found that, comparing 1947 to 1958 and 1958 to 1963, changes in most industries' technical coefficients were rather small (*1*).

[4] For example, the petroleum refining sector can not substitute other inputs for crude petroleum when the price of crude oil goes up. Because the sector cannot operate without crude oil, its members must accept crude petroleum prices offered by producers. In such a case, they would initially absorb the increased costs of crude oil until they can pass on higher costs to their customers.

multipliers is in order. Gross output multipliers express the aggregate effects on production of a specified change in a particular final demand, given the technical production requirements and prices of each industry. The significance of the multiplier rests on how much a change in any final demand directly or indirectly influences the production of a certain industry, which, in turn, leads to changes in income and employment. For instance, suppose the export demand for wheat rises. The direct effect requires increased wheat production and the indirect effect requires increased production in other intermediate goods (for example, fertilizers, energy, repair parts, and so on). Thus, there is a "real" multiplier effect on the economy.

When the price of wheat increases, in contrast, there are no "real" multiplier effects, because no new production is required; rather, the effect will be inflationary. The two types of effects often occur together and they are difficult to separately identify. Yet interpreting price increases in final demand values as *real* increases can lead to wrong conclusions.

AN INPUT-OUTPUT MODEL INCORPORATING PRICE CHANGES

We use a modified input-output model of the U.S. economy to examine the effects upon output and income generation of changes in prices, changes in final demand levels, and changes in both. The theoretical framework of Leontief's input-output model is a static Walrasian general equilibrium model in which there is an equilibrium price for each commodity and relative prices are constant. Further, the market price of a commodity is equal to its cost of production. As expressed by Dorfman, Samuelson, and Solow (*2*), the Leontief model assumes the costs of production; thus, prices of a commodity consist of direct labor cost and costs for use of other goods as intermediate inputs.[5] Therefore,

$$P_j = P_o a_{oj} + P_1 a_{1j} + P_2 a_{2j} + \ldots, + P_n a_{nj};\ j=1, 2, \ldots, n$$

Where:

$P_i a_{ij}$ is the cost per input unit for the *j*th good of the needed *i*th input and

$P_o a_{oj}$ is the direct labor cost (wage, P_o, times needed labor, a_{oj}) (*2*, p. 235).

The price of output *j* depends on the technological coefficients, a_{ij}, and on other input prices. Under the Leontief system, because the a_{ij}'s are constants and all price equations are homogeneous of degree one, dividing this system of equations by the numeraire, P_o, does not change the equality relationship. As in the Walrasian general equilibrium model, relative prices are constant in the Leontief system. In the above formulation, labor is the only primary input; relative prices of commodities will depend only on their direct and indirect labor costs. Any change in the wage rate is reflected in changes in all other prices.

The conventional Dorfman, Samuelson, and Solow presentation of the Leontief model, however, must be expanded if we want a more realistic empirical analysis. The assumption of direct labor costs as the sole factor cost should be expanded to include other factors. Similarly, a more explicit treatment of exports and imports is required. These modifications plus further ones for integrating price changes in an input-output framework of a regional economy are explained in the articles by Lee, Blakeslee, and Butcher (*4*, *5*). The model presented here adapts their model to data from the national I/O table. Their model is modified to consider the effects of changes in prices and final demand in a model open with respect to personal consumption.[6]

The Formal Model

The formal model consists of three sets of equations related to standard input-output structures. The first set states that the total value of output ($P_i O_i$)[7] consists of the value of total final demand:

($P_i t_i$) and the value of all intermediate uses ($P_i \sum_j a_{ij} O_j$).

$$P_i O_i = P_i \sum_j a_{ij} O_j + P_i t_i \quad i=1, 2, \ldots, n \tag{1}$$

The terms in equation (1) can be written in matrix form as

$$D_p\ O = D_p\ A\ O + D_p t \tag{2}$$

or

$$D_p\ (I-A)\ O = D_p t$$

Where:

D_p = an nxn diagonal matrix of prices, P_i

A = an nxn matrix of technical coefficients, a_{ij}'s

O = an $nx1$ column vector of physical output levels, O_i's. Output includes the sum of domestic production and imports.

[5] Italicized numbers in parentheses refer to items in References at the end of this article.

[6] In the initial Lee-Blakeslee-Butcher model, personal consumption expenditures are implicitly assumed as endogenous through a consumption function with unitary elasticities of income and price. In our model, total income in the economy consists of wage and residual income while an autonomous income is also included in the initial model.

[7] Conventional I/O notation uses X to refer to the value of output. We use $P_i O_i$ to facilitate reference to the value of output (X_i or $P_i O_i$) and real output (O_i).

I = an nxn identity matrix

t = an $nx1$ column vector of physical final demands, t_i's

The second component of the model defines total inputs as the sum of income (Y_j), intermediate inputs ($\sum_i P_i a_{ij} O_j$), and imports ($\sum_i P_{mi} m_{ij} O_j$). It defines income as the sum of residual income and wage income:

$$Y = \sum_j r_j + P_L \sum_j w_j O_j \tag{3}$$

Or, in matrix notation:

$$Y = re' + P_L W O \tag{4}$$

Where:

- Y = a scalar of total income
- e = a $1xn$ vector of ones
- P_L = a scalar, the wage rate
- W = $1xn$ vector of physical labor requirement coefficients, w_j's (comparable to Dorfman, Samuelson, and Solow's a_{oj})
- r = a $1xn$ vector of residual income, r_j's

The third component of the model is an expression which defines residual income in each sector:

$$r_j = P_j O_j - \sum_i P_i a_{ij} O_j - P_L w_j O_j - \sum_i P_{mi} m_{ij} O_j; \quad j = 1, 2, \ldots, n \tag{5}$$

[8]

Here, P_{mi} is the price of the ith class of import goods, and m_{ij} is the ith class of import goods needed per unit of jth output. Equation (5) can also be written in matrix form as:

$$r = [eD_p(I-A) - P_L W - eD_{pm} m]\, D_O \tag{6}$$

Where:

- D_O = an nxn diagonal matrix of output totals (O_j's),
- m = an nxn matrix of import coefficients.
- D_{pm} = an nxn diagonal matrix of import price (P_{mi}).

All other symbols are as defined earlier. Equations (2), (4), and (6) constitute the model. They express the relationship between the jointly endogenous variables O (or D_O), Y, and r and the exogenous variables, t, D_p, D_{pm} and P_L.

Estimating Effects of Price Changes

The effects of price changes can be estimated with the set of equations by defining a diagonal matrix, $D_{\Delta p}$, of the ratios of new prices over base year prices, P_i/P_i^o, and substituting $D_{\Delta p}$ for D_p in the equations.[9] The ratio, P_i/P_i^o, is an index number expressing a price for the ith commodity relative to the base period.

Similarly, a change in physical final demand can be represented by multiplying the base period value by an index of change in real final demand, $D_{\Delta t} t$, where $D_{\Delta t}$ is an nxn diagonal matrix of final demand indices (Δt_i's).[10] After making the indicated substitutions, we get equations (7) and (8) for (2) and (6):

$$D_{\Delta p}\,(I-A)\,O = D_{\Delta p}\,D_{\Delta t}\,t \tag{7}$$

$$r = [eD_{\Delta p}\,(I-A) - P_L w - eD_{pm} m]\,D_O \tag{8}$$

The introduction of the terms $D_{\Delta p}$ and $D_{\Delta t}$ makes this input-output model more flexible than the standard model.

We can now separately identify the effects of changes in prices ($D\Delta_p$), changes in physical final demand ($D_{\Delta t}$), or a combination of both ($D_{\Delta p} D_{\Delta t}$) on the output and income generation in an economy.[11] Solving equation (7) for O by premultiplying both sides of the equation by $(I-A)^{-1} D_{\Delta p}^{-1}$ yields the estimate of the new total output (D_O) associated with the changes in prices and level of final demand. Substituting this change in output estimate into equation (8) yields the associated estimate of the value of residual income. Using these values r and O in equation (4) supplies the associated estimate of total income. The value of output expressed in new prices is

---

[8] The definition of income in input-output is synonymous with the value created. Thus, residual income includes proprietors' income, rental income, corporate profits, net interest, business transfer payments, indirect business tax, and capital consumption allowances.

[9] And $D_{\Delta pm}$ for P_{mi} or $D_{\Delta P_L}$ for P_L, if changes in import prices or labor prices are considered, although in this article these prices are held constant.

[10] Where Δt_i equals new real final demand as a ratio of base year real final demand.

[11] In the simple case where only the price and final demand of one sector vary, the change in the value of a sector output is the product of the change in price (P_i) and the change in quantity (O_i); that is, $(1 + D_{\Delta p})(1 + D_{\Delta} o_i)$ or $(1 + D_{\Delta pi} + D_{\Delta} oi + D_{\Delta pi} D_{\Delta oi})$. But our measure of quantity change is final demand ($D_{\Delta t}$), not output, so $(1 + D_{\Delta} o_i)$ becomes $1 + C_{ik} D_{\Delta tk} t_k / O_i$. C_{ik} is the ik element of the $(I-A)^{-1}$ matrix and t_k and O_i are base period final demand in the kth sector and output in the ith sector. It is apparent that the effects on value of a price change influence only that sector and are reflected undiminished. However, effects of a change in final demand influence other sectors as well and they are influenced by the associated input-output multiplier coefficient and the magnitude of final demand in the sector experiencing the change in final demand (sector k).

given by $D_{\Delta p}O$. An examination of equations (7) and (8) shows that price changes do not affect the value of base year output but do affect residual income. On the other hand, changes in real final demand affect output, wage income, residual income, and import payments.

ILLUSTRATIVE EXAMPLE

The interworkings of our economic model may become more apparent from an empirical example in which food grain prices and exports are used. We present results for three cases: a change in price, a change in demand, and a change in price and in demand simultaneously.

The table shows estimates of outputs and incomes which result from the three sets of changes postulated in the food grains sector. All were calculated with the model described in the preceding section. The base year output and income (GNP) are from the U.S. input-output tables for 1967 (*8*). The output and income elements in columns (2), (4), and (6) are those "predicted" by the model, assuming that: 1) the price of food grains has increased 124.3 percent (the actual 1967-75 increase); 2) the final demands for food grains have risen the same amount; and 3) both price and final demand for food grains have jointly gone up 124.3 percent and 41 percent, respectively. The price index chosen is the BLS wholesale price index for food grains. To facilitate the comparison of the real multiplier and inflationary effects, we used the same index (224.3) as the index for real final demand. However, the final demand index 141.0 in column (6) reflects the actual ratio of the volume of food grain exports in 1975 to those in 1967.

Case 1: A Change in Price

The estimated value of food grain output when the food grain price index goes up to 224.3 increases 124.3 percent, and it does not change the value of output for the other sectors. This result occurs because the increased price does not have any real direct and indirect multiplier effects, merely an inflationary effect. An I/O model, because it is a general equilibrium model, assumes a perfectly inelastic demand curve for the output of a sector. Further, a sector's output is equal to the demands (intermediate and final). Thus, an exogenous change in price for the food grain sector would not influence the quantity demanded or supplied which, in turn, precludes this exogenous price change from having output multiplier effects on the rest of the economy.

The food grain price increase, however, does influence the value of the sector output and, consequently, sector income levels, particularly the residual income. In other words, nonwage income in the food grains sector will have a shortrun windfall increase while sectors using food grains will have reduced income because of increased costs of the food grains inputs and an inability to pass along these cost increases. Food grains sector income rises to $4,588.9 million, up 252 percent from $1,303.4 million, while sectors relying on food grains as an important intermediate input experience a reduction in their income. For example, the feed and flour milling sector's income goes down to $173 million from an initial income of $1,968.5 million, a 91.2-percent

Changes in output and income due to postulated changes

Sector	(1) Base year	(2) With price index = 224.3	(3) Change in (2) over (1)	(4) With final demand index = 224.3	(5) Change in (4) over (1)	(6) With price index = 224.3 and final index = 141.0	(7) Change in (6) over (1)
	Million dollars		*Percent*	*Million dollars*	*Percent*	*Million dollars*	*Percent*
Output:							
Food grains	2,643.2	5,928.7	124.30	3,694.4	39.77	6,706.4	153.72
Fertilizers	1,698.1	1,698.1		1,738.0	2.35	1,711.3	.78
Income:							
Food grains	1,303.4	4,588.9	252.07	1,821.7	39.77	5,190.8	298.25
Fertilizers	517.0	517.0		529.2	2.35	521.0	.78
Fats and oils mills	672.5	641.7	−4.58	673.1	.08	641.9	−4.56
Poultry and egg producers	415.4	376.9	−9.27	416.0	.16	377.1	−9.22
Feed and flour mills	1,968.5	173.0	−91.21	1,970.9	.12	173.1	−91.21
Gross national product	795,388	796,435.5	.13	796,403.2	.13	797,200.8	.23

decrease. Poultry and eggs producers and fats and oils mills also lose some income. The last row of column (2) further indicates that when food grain prices go up to 1975 levels, assuming other prices remain at their 1967 level, the income gain to the food grain sector offsets higher costs (lower incomes) in other sectors, to make the nominal value of GNP about $1.1 billion higher.

Within this type of input-output model, equilibrium occurs when cost equals price for each sector. The price increase for food grains disturbs this equilibrium and, for this sector, average revenue (price) exceeds average cost. At the same time, in other sectors, higher food grain costs will be reflected in a higher average cost curve (the amount of the shift depending on the importance of food grain inputs within each sector), without an offsetting shift in the average revenue line. Thus, such sectors experience a drop in income. Our model takes its snapshot right at this point, which is, of course, a disequilibrium solution. Based on economic theory, normal economic forces would bring about a new Walrasian-type equilibrium in which there would be a larger output of food grains and a change in equilibrium output and income levels in some other sectors.

Case 2: A Change in Final Demand

Estimates of outputs and income resulting from increased final demand levels for food grains differ quite markedly from estimates based on the same percentage price increase. A 124.3-percent increase in real final demand results in only a 39.8-percent rise in value of output for the food grain sector, compared with the 124.3-percent gain as a result of the price change.[12] Further, increased final demand for food grains has a real multiplier effect; for example, the value of output in the fertilizers sector increases also, 2.35 percent. Recall that this increase did not occur when prices alone went up. The real multiplier effect of a rise in real final demand raises income in other sectors, in contrast to the income reductions resulting from price increases. The cumulative effects of individual sector increases in income add to about $1.0 billion of additional nominal GNP when the final demand for food grains goes up 124.3 percent.

These different effects are due to the exogenous change in the final demand for food grains, which induces a change in the quantity demanded in the food grains sector. This latter change affects food grain output but not price. The effect on output is reflected in other sectors by inducing demands for inputs. Each of these affected sectors also experiences a change in quantity but not price, so that at no point in the adjustment process are the equilibrium price and cost conditions changed. The economy remains in equilibrium but at a higher level of output.

A comparison of columns (3) and (5) of the table illustrates an important difference between the effects of a price increase and a rise in the level of real final demand. An increase in a sector price adversely affects those sectors to which the sector is linked forward in the production process (sectors to which it sells its output). An increase in real demand benefits those sectors to which the sector is linked backward in the production process (sectors from which it purchases its inputs).

Case 3: A Change in Both Price and Demand

The last two columns in the table show the estimated effect of a more realistic situation, simultaneously allowing both price and demand to vary. The indices used are actual figures for 1975. When the price index goes up to 224.3 percent and physical final demand index goes up to 141.0 simultaneously, the food grain sector's output and income go up substantially, 153.7 and 298.3 percent, respectively. No other sectors are significantly benefited. The fertilizers sector, which showed a 2.35-percent increase in income when final demand for food grains went up 124.3-percent, now shows a 0.78-percent increase. Three other sectors discussed as being particularly adversely affected by the price increase still lose some income. For these sectors, the inflationary effect of the food grain price increase outweighs the multiplier effect of increased final demand for food grains. However, assuming other sectors' price and demand do not change, the simultaneous increases in price and final demand for food grains generate enough nominal GNP to offset lower levels in other sectors. The result is a net $1.8-billion increase in nominal GNP, as shown in the last row of column (6).

CONCLUSION

The results presented above have significant implications for persons concerned with the impact analysis of changing final demands on an economy through use of an input-output model. Changes in price ($D_{\Delta p}$) and physical final demand ($D_{\Delta t}$) not only affect an economy differently, but also influence different segments of that economy. With a higher price for food grains, even though the food grains sector income and nominal GNP go up, some sectors lose income. When the final demand for food grains increases, however, no sectors will lose income but they will gain income at varying rates.

In a standard input-output model, the real multiplier effects are larger as endogenous sectors are more interdependent. As the $(I-A)^{-1}$ matrix shows, this increase is due to larger direct and indirect links (the real multipliers) among sectors. These real multipliers, when multiplied by changes in exogenous final demands, show increased production requirements for all interdependent sectors. As illustrated here, however, because of forward linkages when prices change, more income is generated in the economy when the endogenous sectors depend less on each other. Thus, when the inflationary effects are considered, the greater effects are not necessarily

[12] See footnote 11.

associated with higher interdependency. Therefore, for impact analysis of changes in final demands on the economy, it is highly important to know if the changes are in price ($D_{\Delta p}$), in real final demand ($D_{\Delta t}$), or a combination of both ($D_{\Delta p} D_{\Delta t}$).

Both the model and results represent shortrun analysis. For example, we showed that when the price of food grains increases, the feed and flour mills sector would lose 91.2 percent of its income. This situation obviously is untenable and, to remain in operation, the mills will eventually have to transfer the increased input costs to their customers. In other words, the sector will eventually be forced to increase its product price. This identification of sectors subject to unusual cost pressures could be useful information for policymakers because inflationary trends do not come at once but by chain effects over time. Although the model does not predict the timing of these chain effects, it can "anticipate" which sectors will be likely to experience cost pressures. With this information, planners can make appropriate adjustments to the expected inflationary effects.

A final caveat seems appropriate. The price and final demand changes analyzed here are exogenous, independent phenomena. Admittedly, the examples do not represent a large subset of the many price and output changes constantly occurring in a dynamic economy. We hope, however, that this analysis may contribute to an understanding of appropriate use and interpretation of input-output analysis. Some insight may be given into the influence on an economy of both inflation and growth in real demand.

REFERENCES

(1) Bezdek, H. Robert and Robert M. Wedling. *Postwar Changes in U.S. Input-Output Relationships: Summaries of Research Projects Conducted at the Bureau of Economic Analysis.* Presented at the Third World Congress of the Econometric Soviets, Toronto, Canada, Aug., 1975.

(2) Dorfman, Robert, Paul A. Samuelson, and Robert M. Solow. *Linear Programming and Economic Analysis.* McGraw-Hill Book Co., New York, 1958.

(3) *Fortune.* July 1974.

(4) Lee, Chinkook. "The Effects of an Exogenous Change in Prices on a Regional Economy." Unpubl. Ph.D. thesis, Wash. State Univ., 1974.

(5) Lee, Chinkook, Leroy L. Blakeslee, and Walter R. Butcher. *Effects of Exogenous Changes in Prices and Final Demand for Wheat and Energy Resources on the Washington Economy: An Input-Output Analysis.* Pullman: Wash. State Univ., Coll. Agr. Res. Ctr., Tech. bul. 85, June 1976. 25 pp.

(6) Leontief, Wassily. *The Structure of American Economy, 1919-1939.* 2nd Edit., Oxford Univ. Press, New York, 1965.

(7) Patinkin, Don. *Money, Interest, and Prices.* 2nd. Edit., Harper and Row, New York, 1965.

(8) U.S. Department of Commerce, Bureau of Economic Analysis. *Survey of Current Business.* Vol. 54, No. 2, Feb., 1974.

(9) U.S. Department of Labor, Bureau of Labor Statistics. *Wholesale Prices and Price Indexes.* Various issues.

CRITERIA FOR CRITIQUING SOCIAL SCIENCE COMPUTER MODELS WITH APPLICATION TO BARR-GALE MODEL FOR CONSUMER PRICE INDEX OF FOOD

By Howard Morland, Narasimhan P. Kannan, and Dennis L. Meadows*

The authors propose six questions relevant to the evaluation of all social system models, and apply them to the Barr-Gale model for forecasting the Consumer Price Index for Food. While analysts invest much effort in developing new economic models, relatively little attention is paid to critiquing existing models. For models to become scientifically acceptable and widely used tools for policy design in the social sciences, they must be accompanied by complete documentation and data. Then independent investigators can confirm published results and determine a model's sensitivity to changes in assumptions. Greater emphasis on critical analysis and standard procedures for evaluation will help potential users evaluate models for accuracy and suitability for their purposes.

Keywords: Food prices, farm prices, forecasts, model testing, model critique.

INTRODUCTION

Much attention has been given to the task of formulating social system models that forecast prices. Much less effort has been devoted to analyzing such models and putting them to practical use. The lack of interest in critiquing social system models is illustrated by the fact that numerous econometric models are published in journals such as *Agricultural Economics Research*, yet no critical evaluations of such models by independent researchers are published. Decisionmakers who could profitably employ accurate forecasting models often lack the statistical skills necessary to evaluate them, to choose the most useful model from among those available, and to interpret the outputs with confidence. In the absence of any generally accepted system for evaluating social system models, good and bad models alike are frequently ignored.

In the physical sciences, models are expected to pass tests of independent verification and critical analysis. Premiums are placed on simplicity, accuracy, and usefulness. If the art of social system modeling is to advance toward the level of its physical science counterpart, ways must be developed for independent researchers to verify conclusions and test the predictive accuracy of the models of other social scientists.

There is no one procedure that will completely analyze all models, but the questions proposed below cover the areas of greatest concern in most social science models. The critical process must be flexible enough to accommodate a wide variety of subjects and modeling techniques, and yet reveal any flaws of either application or method.

- Is the model's output unambiguous? Does it consist of variables that can be identified and measured in the real system?
- How accurate is the model? Does it closely reproduce historical data; were any computational errors involved in its construction?
- Can a potential user understand the way the model works and hence evaluate its structure in relation to reality?
- Is documentation complete enough so that a potential user can independently confirm the published results and test their sensitivity to reasonable changes in the model's assumptions?
- Is the theoretical basis of the model sound?
- Can a simpler model with equivalent or better performance be constructed?

We applied these questions to an econometric model constructed to predict the Consumer Price Index for Food on a quarterly basis. This model was developed by T. W. Barr and H. F. Gale and published in *Agricultural Economics Research* in January 1973 (*1*, pp. 1-14).[1] Their model was chosen because the description was unusually complete, suggesting that independent analysis should be feasible based only on information in the article; the goals of the model are specific, so that interpretation of its output is unambiguous; and recent drastic increases in food prices make the model of current interest.

ANALYSIS OF THE MODEL

Description

The model consists of six equations. Five are simultaneous linear equations with five unknowns which can be solved to yield five independent formulae, one for each unknown. The sixth equation depends on the other

---

*Howard Morland is a graduate student working toward a masters degree; Narasimhan P. Kannan is a Ph.D. candidate; and Dennis L. Meadows is an associate professor of engineering and business. All three are associated with the Systems Dynamics Group, Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire.

[1] Italicized numbers in parentheses refer to items in References at the end of this article.

five. The five equations are published in two forms:

- Unsolved, simultaneous equations, called the structural equations, with coefficients obtained through two-stage least squares regression analyses of the base period data;
- Solved, independent equations, called the reduced-form equations, with coefficients produced by inversion and multiplication of the coefficient matrices of the structural equations.

All the equations appear in the appendix.

Users of the model are advised by Barr and Gale to perform calculations with the reduced-form equations as the two forms are mathematically equivalent and the reduced-form equations do not require the use of matrix algebra nor access to a high-speed computer.

The model requires quarterly inputs of seven variables, six dummy variables, numerical values for five model parameters in the previous quarter, and a time trend variable. With this information, the model produces values for six output variables, five of which serve as inputs for the next quarter's calculations. For the first quarter's calculations, the model must have historical values of these five variables.

The seven variables of input data are forecasts obtained in the form of expert opinions. They include forecasts of the wage rate of workers in the food marketing industry and of various food prices. Output forecasts are not generated beyond quarters for which the model receives input forecasts. Therefore the modeling process is simply a weighting scheme by which predictions of seven variables are converted into predictions of more useful quantities.

Documentation

Input Information. Six of the inputs are averages of agricultural prices—prices received by farmers for meat, dairy products, poultry, oil crops, fruits, and vegetables. Historical values of these variables are published monthly in *Agricultural Prices* by USDA's Crop Reporting Board. Forecasts are available from commodity specialists. The seventh input is an estimate of wages paid in the food marketing industry, historical values of which appear quarterly in the ERS publication *Marketing and Transportation Situation*. Wage forecasts are, presumably, available from the U.S. Department of Labor, although Barr and Gale do not suggest where the model user may obtain such forecasts.

Output Information. The two primary outputs, the Consumer Price Index for Food at Home and the Consumer Price Index for All Food, are published monthly by the Labor Department's Bureau of Labor Statistics in *Monthly Labor Review*. The other four outputs—the farm values and the farm-retail price spreads for both livestock and crop-food products—are components of USDA's market basket price, published in *Agricultural Outlook*. Lagged values of five of the six outputs (all but the farm-retail price spread for livestock), re-enter the model as inputs; consequently, historical values of the five quantities must be supplied to the model for its first iteration.

We were not always able to tell from the text exactly which values should be extracted from the three publications and entered into the model. Moreover, all inputs, except the dummy and time-trend variables, take the form of indices (1967=100). As many of the inputs are published in current dollars only, a readily available compilation of the index values used in the model would save users and evaluators time and effort. Where such information seems too bulky to publish, it should appear in a separate appendix or user's manual, which could be available from the authors on request. Despite the data gaps, the Barr-Gale documentation is unusually complete: all the equations were published.

Errors

When we attempted to run the model, we discovered some miscellaneous errors.

The Sixth Equation. The equation for the Consumer Price Index for All Food, TCPIF, which did not belong to the set of five simultaneous equations, was, itself, presented as five equations. Unable to interpret the equations unambiguously, we contacted one of the authors by telephone and were instructed to ignore the first of the TCPIF equations, combine the other four, and solve for TCPIF. Such an interpretation of the equations presented was not apparent from the text.

Typographical and Editing Errors. In attempting to reproduce the results of the published prediction-interval test for the first quarter of 1972, we obtained a value of 128.2 for CPIF, the Consumer Price Index for Food at Home, compared with the Barr-Gale figure of 118.2. Predictions for subsequent quarters showed similar deviations from the Barr-Gale values. After eliminating the possibility of error in the input data, we resolved the set of structural equations on the assumption (which later proved correct) that the reduced-form equations contained a typographical error.

Our calculations reproduced the coefficients of the published reduced-form equations to six-digit accuracy. According to our results, the 19th term in the equation for CPIF should read $-0.03836\ FVC_{t-2}$ rather than $+0.03836\ FVC_{t-2}$ as the term appears in the published equation. After making the indicated sign change, we obtained a prediction of 118.7 for CPIF for the first quarter of 1972. Our figure is acceptably close to the 118.2 cited by Barr and Gale as their prediction for the same quarter.

A second typographical error in the reduced-form equation for FVL placed the wrong time subscript (2) on the variable FVC_{t-3}. This mistake does not significantly influence the model predictions.

From our new set of reduced-form equations, we recorded the following differences between the con-

stant terms resulting from our calculations and the published terms:

Variable	Barr-Gale	Our recalculations
Farm value of livestock	21.35997	23.45924
Farm-retail price spread for livestock	6.64355	5.87997
Consumer Price Index for Food	29.25527	36.93179

These three discrepancies in the reduced-form equations are resolved if the constant term in the structural equation for CPIF is assumed to be -4.08410 rather than +3.40227, as published.

The text provides no explanation for the failure of the two forms of the model, structural and reduced, to be mathematically equivalent. The explanation, which Barr helped us locate through telephone contact, is that the structural equations contained the constant term error and the reduced-form equations contained the numerical sign and time subscript errors.

One way to avoid such errors is to print computer output directly rather than to retype equations and computer-generated results. The appendix contains a complete listing of the Barr-Gale equations in the form of output generated by a short BASIC computer program. The three errors in the equations have been corrected to make the two forms of the model equivalent. Such programs can take computer-generated numbers and print them in a publishable format.

Forecasting Ability

The model was developed using data from 1960 through the third quarter of 1971. Its performance was demonstrated by Barr and Gale using data from the next three quarters. Sufficient time has now elapsed to permit a more complete test of the model's predictive powers.

Rather than attempt to evaluate performance with forecasted input estimates, we have chosen to supply historical values. Thus, we can determine the maximum predictive power of the model without any errors introduced by forecasts of the input data. This approach finesses a real difficulty: the model requires inputs based on subjective opinions.

A regression model's coefficients are most accurate near the mean of the data from which the model is constructed (*3*, pp. 21-24). The normalized independent variables for the base period range from values of around 90 in 1960 to around 120 in 1971. Given the usual assumption about variance of the coefficients, the expected deviation between forecast and actual prices will increase as values of the inputs move away from their base period averages of approximately 100. Since this model's forecasts begin at the high end of the data range and move beyond, the model operated outside its range of greatest accuracy in our tests.

The figure shows how the model would have forecast each of the six outputs during 1972-74 if perfect predictions had been available for each of the input variables, if the model were updated quarterly, and if projections were made for only one quarter in advance. The graphs supply visible evidence that the Barr-Gale model, like many others, has performed poorly since the end of 1973. The average deviation between forecast and actual values for 1974 ranges from 58.8 percent for the farm value of crops (FVC), to 2.8 percent for the farm-retail price spread for livestock (FRSL). The FVC error clearly reduces the utility of the model.

Reasons for Poor Performance

Sensitivity analysis reveals that the wage input and certain constants are by far the most important driving forces in the model and in large part they are responsible for the model's poor predictive performance. For instance, the equation for the farm value of crops, FVC, has a constant term of 74.5 index points (an index point is 1 percent of the total in 1967, the index base year). The large constant term, which has no real-world analog, holds the forecast values as many as 90 index points below the actual values by the end of the test period. Significantly, the equation for the farm-retail price spread for livestock, FRSL, has the smallest constant term, 6.6 index points, and it exhibits by far the best performance.

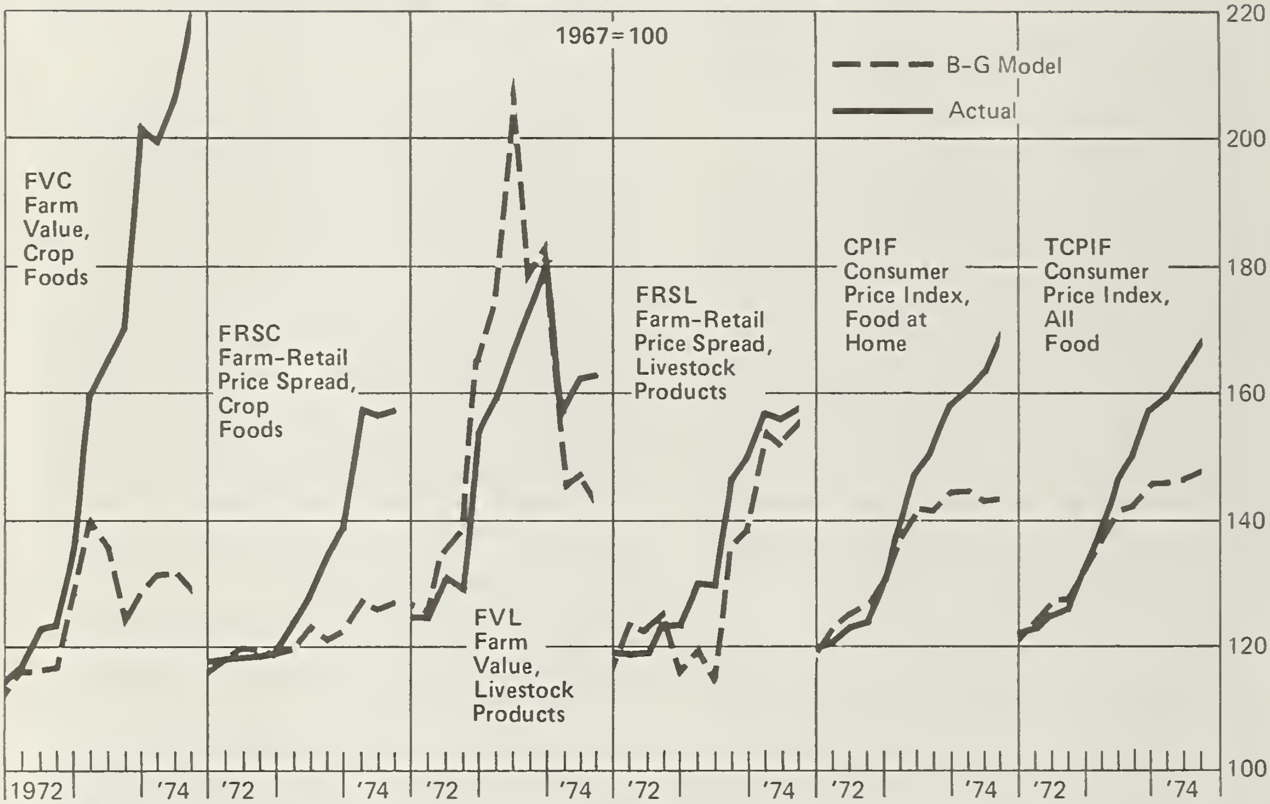
The six-digit coefficients and the large number of terms in each equation can obscure the strong sensitivity of the model to wages, and its lack of sensitivity to prices. The sensitivity of simple models, such as the Barr-Gale model, can be analyzed directly. By inspecting the coefficients, the user can obtain the necessary information about sensitivity of the equations to changes in independent variables.

In the table we list the 23 terms of the equation for CPIF, with their average values for the index base year of 1967. Prices received for meat, PRM, contributed 6.652 index points to the CPIF predictions in that year. Therefore, a 50-percent increase over the 1967 values of prices received for meat would increase the predicted Consumer Price Index for Food at Home by 3.326 index points, or about 3 percent. The equation is more sensitive to PRM than to any other price input.

On the other hand, the importance of wages in the CPIF equation is overwhelming. Half the value of CPIF, 49.428 index points, is attributable to the current and lagged values of WFMI, wages of food marketing workers. Since the constant term is almost 30 percent of the value of CPIF, 29.25527 index points, the remaining 20 terms of the equation, including all inputs of food prices and distributor markups, contribute just over 20 percent of the total prediction.

The negative signs on the coefficients for the time trend, the farm value, and the farm-retail price spread

Performance of the Barr-Gale model



NOTE: For each of the six equations in the model, forecasts are made for the 12 quarters of 1972-74 using actual values of all current and lagged input variables. Actual values of the output variables are shown for comparison.

Sensitivity analysis of reduced-form equation for CPIF

Coefficient	Input	Product	Term name
29.25527	1	29.25527	(constant)
+0.06652	100	6.652	Prices received for meat (t)
+0.02552	100	2.552	Prices received for dairy (t)
+0.01662	100	1.662	Prices received for poultry (t)
+0.01054	100	1.054	Prices received for oil (t)
+0.01262	100	1.262	Prices received for fruit (t)
+0.01947	100	2.947	Prices received for vegetables (t)
−0.09859	0.25	−0.02465	Dummy, first quarter (t)
+0.43540	0.25	0.1089	Dummy, second quarter (t)
+0.76243	0.25	0.1906	Dummy, third quarter (t)
−0.80680	0	0	Dummy, 1960-64 (t)
−0.54244	1	−0.54244	Dummy, 1967-68 (t)
+0.18579	100	18.579	Food marketing wages (t)
+0.65825	0.25	0.16456	Dummy, fourth quarter (t)
−0.09970	30.5	−3.04085	Time trend (t)
+0.07819	100	7.819	Farm value of livestock (t−1)
+0.06774	100	6.774	Farm value of livestock (t−2)
+0.02395	100	2.395	Farm value of crops (t−1)
−0.03836	100	−3.836	Farm value of crops (t−2)
−0.00347	100	−0.347	Farm value of crops (t−3)
−0.00291	100	−0.291	Farm-retail spread, crops (t−1)
−0.02930	100	−3.930	Farm-retail spread, crops (t−2)
+0.30849	100	30.849	Food marketing wages (t−1)
Total		100.2524	

Note: Because all data are fed into the model with the index 1967 equal to 100, the contribution of each data variable to the total is roughly equal to 100 times the coefficient, exactly so in 1967 when all data inputs are equal to 100. Quarterly dummy variables average 0.25 for each year. The time trend variable averages 30.5 for 1967; its value for each quarter equals the number of elapsed quarters since the first quarter of 1960. Dummy variables for the wheat subsidy and the wheat allotment programs have values of zero and 1.0, respectively, in 1967. Prices received are prices received by farmers.

apparently reflect relationships that were valid during the sixties but no longer hold today. A regression analysis on more recent data would certainly be expected to yield positive coefficients for such terms.

Because regression analysis captures the statistical properties of coincidental variation of quantities rather than their causal interrelationships, the terms of the model's equations may not, and in this case do not, reflect the real-world contributions of the input quantities to the totals. Recent dramatic increases in consumer prices for food have not been accompanied by similar increases in wages for food workers, despite the close correlation of the two quantities during the sixties. Consequently, the model could not have predicted recent events, and, as we have seen, it does not, even with perfect-input forecasts. The minor importance (and sometimes negative influence) of food producer prices and distributor markups in the CPIF equation are responsible for the model's poor performance since the recent increase in food prices began.

To answer whether there is a simpler model for CPIF which will perform adequately, we developed an exponential smoothing model which is considerably less complicated than regression analysis.[2] It followed the actual trends more closely than the Barr-Gale model, but it too had weaknesses. Since the last quarter of 1972 marks the end of one linear trend and the beginning of another, the smoothing model did not provide accurate four-quarter projections for 1973.[3]

CONCLUSIONS

Referring, then, to our original test questions, which we believe all models should be subjected to, we draw six conclusions.

The model predicted the CPIF acceptably well for its published test period and for the first three quarters

[2] For an explanation of exponential smoothing, see (*2*, pp. 128-135).

[3] Detailed documentation of this model is available from the System Dynamics Program Office, Box 8000, Dartmouth College, Hanover, N.H. 03755. Request "A Critique of the Barr-Gale Econometric Model for Forecasting the Consumer Price Index for Food." DSD #45, $1.30.

after its publication. But, as with many other CPIF models, the radical changes in the influences on the index in 1973 caused great errors in the model's forecasts thereafter. While it would be possible (though difficult) to revise the model to reflect these changes, any later similar changes would cause another breakdown. A quantity which is increasing steadily would not be expected to return to the range of its historical values. Yet only within the historical range can a least squares regression model be expected to have reasonable accuracy. While a base period of almost 12 years may seem desirable, in the Barr-Gale model such a long period actually serves to increase the difference between the mean value of the base period data and the values which are being forecast.

The model's output, being a published number, is measurable and unambiguous; hence, the model's performance is easily rated.

With the help of the sensitivity analysis published here, potential users should find the model comprehensible, and should be able to evaluate its strengths and limitations for their own purposes.

The Barr-Gale model is more completely presented and documented than most similar models in the literature, but improvements are still necessary. Because the model's inputs are indexed to 1967=100, it is easy to understand the equations, though developing indexed data is a nuisance.

We have demonstrated that a simpler model with comparable predictive ability is possible.

The underlying difficulty with both the Barr-Gale model and the exponential smoothing model is that they are mathematically derived projections based on statistical coincidence: when the nature of the marketplace changes radically, as it did in 1973, such models no longer reflect real-world behavior.

REFERENCES

(1) Barr, T. N. and H. F. Gale, "A Quarterly Forecasting Model for the Consumer Price Index for Food". *Agr. Econ. Res.* 25 (1):1-14, January 1973.

(2) Brown, R. G., *Smoothing, Forecasting, and Prediction of Discrete Time Series*. Prentice-Hall, 1963.

(3) Draper, R. N. and H. Smith, *Applied Regression Analysis*. John Wiley and Sons, 1966.

APPENDIX

UNKNOWN TERMS OF THE STRUCTURAL EQUATIONS

		EQUATION NUMBER		
ONE (FVC)	TWO (FRSC)	THREE (FVL)	FOUR (FRSL)	FIVE (CPIF)
1.0000 FVC	0.1442 FVC	0.0000 FVC	0.0000 FVC	-0.1535 FVC
-0.4644 FRSC	1.0000 FRSC	0.0000 FRSC	0.0000 FRSC	-0.2758 FRSC
0.0000 FVL	0.0000 FVL	1.0000 FVL	0.3685 FVL	-0.2253 FVL
0.0000 FRSL	0.0000 FRSL	0.3966 FRSL	1.0000 FRSL	-0.3656 FRSL
0.0000 CPIF	0.0000 CPIF	-0.2335 CPIF	0.0000 CPIF	1.0000 CPIF

KNOWN TERMS OF THE STRUCTURAL EQUATIONS

		EQUATION NUMBER		
ONE (FVC)	TWO (FRSC)	THREE (FVL)	FOUR (FRSL)	FIVE (CPIF)[1]
49.79600	63.91080	17.16370	14.51470	-4.08410
0.00000 PRM	0.00000 PRM	0.61150 PRM	0.00000 PRM	0.00000 PRM
0.00000 PRD	0.00000 PRD	0.23460 PRD	0.00000 PRD	0.00000 PRD
0.00000 PRP	0.00000 PRP	0.15280 PRP	0.00000 PRP	0.00000 PRP
0.09640 PRO	0.00000 PRO	0.00000 PRO	0.00000 PRO	0.00000 PRO
0.11550 PRF	0.00000 PRF	0.00000 PRF	0.00000 PRF	0.00000 PRF
0.26960 PRV	0.00000 PRV	0.00000 PRV	0.00000 PRV	0.00000 PRV
0.00000 DFQ	0.00000 DFQ	-0.90640 DFQ	0.00000 DFQ	0.00000 DFQ
0.00000 DSQ	1.30530 DSQ	0.00000 DSQ	0.00000 DSQ	0.00000 DSQ
0.00000 DTQ	2.28570 DTQ	0.00000 DTQ	0.00000 DTQ	0.00000 DTQ
-7.38160 DWS	0.00000 DWS	0.00000 DWS	0.00000 DWS	0.00000 DWS
-4.96290 DWA	0.00000 DWA	0.00000 DWA	0.00000 DWA	0.00000 DWA
0.00000 WFMI	0.55700 WFMI	0.00000 WFMI	0.00000 WFMI	0.00000 WFMI
0.00000 D4Q	0.00000 D4Q	0.00000 D4Q	1.98420 D4Q	0.00000 D4Q
0.00000 T	0.00000 T	0.00000 T	-0.46900 T	0.05450 T
0.00000 FVL-1	0.00000 FVL-1	0.00000 FVL-1	0.23570 FVL-1	0.00000 FVL-1
0.00000 FVL-2	0.00000 FVL-2	0.00000 FVL-2	0.20420 FVL-2	0.00000 FVL-2
0.00000 FVC-1	0.07180 FVC-1	0.00000 FVC-1	0.00000 FVC-1	0.00000 FVC-1
0.00000 FVC-2	-0.11500 FVC-2	0.00000 FVC-2	0.00000 FVC-2	0.00000 FVC-2
0.00000 FVC-3	-0.01040 FVC-3	0.00000 FVC-3	0.00000 FVC-3	0.00000 FVC-3
-0.02660 FRSC-1	0.00000 FRSC-1	0.00000 FRSC-1	0.00000 FRSC-1	0.00000 FRSC-1
-0.35960 FRSC-2	0.00000 FRSC-2	0.00000 FRSC-2	0.00000 FRSC-2	0.00000 FRSC-2
0.00000 WFMI-1	0.00000 WFMI-1	0.00000 WFMI-1	0.92990 WFMI-1	0.00000 WFMI-1

Note: Each of the five simultaneous equations is listed in a separate column. Terms with dependent, or unknown, variables are grouped at the top of each column; constant terms and terms with independent, or known, variables are grouped below. Sign changes have been made in the top section, so that each group of unknown terms is equal to the corresponding group of known terms. Numbers following term names are time subscripts. Terms with no subscripts are current to the quarter being forecasted; others are lagged by the number of quarters indicated by the subscript.

[1] The constant term in the fifth equation has been changed to make the constants of the structural equations algebraically equivalent to those of the published reduced-form equations.

MATRIX ALGEBRA SOLUTION TO THE STRUCTURAL EQUATIONS

EQUATION NUMBER ONE (FVC)	TWO (FRSC)	THREE (FVL)	FOUR (FRSL)	FIVE (CPIF)
74.48798*	53.16963	21.35997	6.64355	29.25527
0.00000 PRM	0.00000 PRM	0.73436 PRM	-0.27061 PRM	0.06652 PRM
0.00000 PRD	0.00000 PRD	0.28173 PRD	-0.10382 PRD	0.02552 PRD
0.00000 PRP	0.00000 PRP	0.18350 PRP	-0.06762 PRP	0.01662 PRP
0.09035 PRO	-0.01303 PRO	0.00288 PRO	-0.00106 PRO	0.01054 PRO
0.10825 PRF	-0.01561 PRF	0.00345 PRF	-0.00127 PRF	0.01262 PRF
0.25268 PRV	-0.03644 PRV	0.00806 PRV	-0.00297 PRV	0.02947 PRV
0.00000 DFQ	0.00000 DFQ	-1.08850 DFQ	0.40111 DFQ	-0.09859 DFQ
0.56814 DSQ	1.22337 DSQ	0.11907 DSQ	-0.04388 DSQ	0.43540 DSQ
0.99486 DTQ	2.14224 DTQ	0.20850 DTQ	-0.07683 DTQ	0.76243 DTQ
-6.91831 DWS	0.99762 DWS	-0.22063 DWS	0.08130 DWS	-0.80680 DWS
-4.65141 DWA	0.67073 DWA	-0.14834 DWA	0.05466 DWA	-0.54244 DWA
0.24244 WFMI	0.52204 WFMI	0.05081 WFMI	-0.01872 WFMI	0.18579 WFMI
0.00000 D4Q	0.00000 D4Q	-0.74162 D4Q	2.25749 D4Q	0.65825 D4Q
0.00000 T	0.00000 T	0.19058 T	-0.53923 T	-0.09970 T
0.00000 FVL-1	0.00000 FVL-1	-0.08810 FVL-1	0.26816 FVL-1	0.07819 FVL-1
0.00000 FVL-2	0.00000 FVL-2	-0.07632 FVL-2	0.23232 FVL-2	0.06774 FVL-2
0.03125 FVC-1	0.06729 FVC-1	0.00655 FVC-1	-0.00241 FVC-1	0.02395 FVC-1
-0.05005 FVC-2	-0.10778 FVC-2	-0.01049 FVC-2	0.00387 FVC-2	*-0.03836 FVC-2
-0.00453 FVC-3	-0.00975 FVC-3	*-0.00095 FVC-3	0.00035 FVC-3	-0.00347 FVC-3
-0.02493 FRSC-1	0.00359 FRSC-1	-0.00080 FRSC-1	0.00029 FRSC-1	-0.00291 FRSC-1
-0.33703 FRSC-2	0.04860 FRSC-2	-0.01075 FRSC-2	0.00396 FRSC-2	-0.03930 FRSC-2
0.00000 WFMI-1	0.00000 WFMI-1	-0.34756 WFMI-1	1.05798 WFMI-1	0.30849 WFMI-1

EQUATION NUMBER SIX (TCPIF)

TCPIF = 0.2913 + 0.9592 TCPIF-1 + 0.7804 (CPIF - 0.9592 CPIF-1) + 0.4047 (T - 0.9592 T-1)

*Note: These equations differ from the published reduced-form equations in the numerical sign of the 19th term (FVC-2) of the 5th equation and in the time subscript of the 20th term (FVC-3) of the 3rd equation.

AN APPROACH TO UNIQUE SOLUTIONS FOR CONSTANT-ELASTICITY COMMODITY MODELS

By Gerald E. Plato*

Unique solutions are more difficult to guarantee for commodity models that have nonlinear simultaneous equations than for those with linear ones. The nonlinear case requires determination of uniqueness before a solution is attempted while uniqueness in the linear case is determined as a byproduct of the solution procedure. Unique solutions are important because they are necessary for unambiguous results (that is, results that can always be duplicated). This article explains an approach for guaranteeing unique solutions for commodity models specified with a nonlinear equation type often used in economics, the constant-elasticity equation. This choice allows researchers the option of using secondary data sources (parameter estimates) in developing commodity models.
Keywords: Nonlinear commodity models, unique solutions, Newton's method.

INTRODUCTION

An ongoing task for economists is to explain the behavior of market prices and quantities, and to forecast and project them. The theory of general equilibrium, involving equations that simultaneously determine many prices and quantities, has been available for aiding in these functions since the 1870's. Shortcuts of obtaining the necessary data for these equations are now available for empirical applications (*9*, *6*).[1] Also, high-speed computers are now available and can be used in conjunction with trial and error methods derived from those of Gauss and Newton for solving complex nonlinear models (*8*, *10*). Thus, general equilibrium theory and recent technological advances provide researchers willing to assume constant elasticities the option of using secondary data sources in developing models that simultaneously determine many commodity prices and quantities.

These trial and error procedures do not guarantee unique solutions. Uniqueness has been a long-time concern in general equilibrium theory. It is well recognized that a system of excess demand (demand minus supply) equations describing one less than the total collection of markets has an equal number of independent equations and unknowns. Further, this equality is not sufficient to guarantee a unique equilibrium solution (*7*, p. 350; *11*, p. 160). Recently, a number of economists have developed sufficient conditions for uniqueness of the general equilibrium model. Results provided by Arrow and Hahn (*4*) in this effort were used in developing an approach for guaranteeing unique solutions for a commodity projections component model. This model is specified with simultaneous and constant-elasticity equations. It is used in ERS to make commodity projections and it is part of the National Interregional Agricultural Projections Model (NIRAP) (*5*, p. 47).

The purpose of this article is to explain the approach used to guarantee unique solutions for this commodity projection component model. The first step in the approach involves a discussion of the determination of uniqueness in commodity models with linear simultaneous equations. Next, the use of a trial and error procedure, the Newton algorithm, in solving nonlinear commodity models is explained and its use for solving linear commodity models is discussed as being a special case. Finally, uniqueness in the linear case is extended to the commodity projections component model. This extension is based upon calculations used in finding an equilibrium solution by the Newton algorithm.

LINEAR COMMODITY MODELS

Let the following equation represent a commodity model containing N commodities specified with linear-simultaneous equations:

$$BP + \Gamma X = 0. \tag{1}$$

The model is shown in the form of excess-demand (demand minus supply) equations. B is an N by N coefficient matrix for the commodity prices in the N by 1 P vector. Γ is an N by K coefficient matrix for the exogenous variables in the K by 1 X vector.[2] If the B matrix is nonsingular, the solution can be found by equation 2 below:

$$P = -B^{-1} \Gamma X. \tag{2}$$

*Gerald Plato is an agricultural economist with the National Economic Analysis Division, ERS.

[1] Italicized numbers in parentheses refer to items in References at the end of this article.

[2] Since the model is not concerned with all possible commodities, the Nth + 1 commodity is considered to be the numeraire or an aggregate of all the commodities omitted.

In the linear case, trial and error procedures are not required; one iteration produces the equilibrium solution. Also, if B is nonsingular, the solution is unique.[3] However, obtaining uniqueness like stability is more elusive for nonlinear models.

SOLUTION PROCEDURE FOR NONLINEAR COMMODITY MODELS

The Newton algorithm can be used to solve nonlinear commodity models.[4] The algorithm proceeds by finding successive improvements in an initial guess of an equilibrium price vector.[5] An improvement is calculated by solving for P minus P_O or Δ P in the following set of equations:

$$f(P_O, X) + B(P_O, X)\,(P-P_O) = 0 \qquad (3)$$

where:

$f(P_O, X)$ equals the vector of commodity excess demands at the initial guess of equilibrium prices, P_O, or at the prices calculated in the previous iteration, X represents the exogenous variables at preselected levels;

$B(P_O, X)$ is an N by N matrix of first partial derivatives of excess demand equations with respect to commodity prices evaluated at initial guesses of the equilibrium prices or at the prices calculated in the previous iteration and at the preselected levels of the exogenous variables;

and P equals the "improved" vector of commodity prices.

Equation (3) is based on the Taylor series expansion about the price vector P_O. This expansion for the excess demand equations is shown below in equation (4):

$$\begin{aligned} f(P, X) &= f(P_O + \Delta P, X) \\ &= f(P_O, X) + f'(P_O, X)\,(P-P_O) \\ &\quad + f''(P_O, X)\,(P-P_O)^2 + f'''(P_O, X)\,(P-P_O)^3 \\ &\quad + \ldots\ldots \\ &= 0 \end{aligned} \qquad (4)$$

The vector P of improved prices in equation (4) is assumed to be the equilibrium price vector (that is, the price vector that makes all the excess demand equations equal to zero). For equation (3), all squared and higher order terms shown in equation (4) are assumed equal to zero.

Solving the linear system in equation (3) would give a vector of prices that would eliminate excess demands if the system of equations followed the linear tangents rather than the underlying nonlinear curves. However, since the excess demand curves are nonlinear, the P vector of commodity prices that is calculated may not be close enough to an equilibrium solution. In fact the Newton algorithm may fail to move the commodity prices closer to equilibrium. If failure occurs, the price changes can be dampened by an arbitrary proportion or new starting values for the endogenous variables (i.e., the commodity prices) can be selected. When "close" to an equilibrium solution, the effects of the squared and higher order terms in equation (4) become small. The linear tangents then sufficiently approximate the underlying nonlinear curves and the Newton algorithm can proceed unaided to achieve the desired closeness to equilibrium. Prior to the second and following iterations by equation (3),vector P_O is set equal to P.

If a linear model is solved using equation (3), only one improvement in prices (that is, one iteration) would be needed and the solution obtained would be the same as for equation (1). In the linear case, the initial guesses can be set equal to zero and the Δ P would equal the equilibrium prices.

As with linear simultaneous equations, uniqueness for nonlinear-simultaneous equations depends on the B matrix. In the remainder of this article, I discuss sufficient conditions to impose on the B matrix that will guarantee unique solutions for constant-elasticity commodity models.

GUARANTEEING UNIQUENESS IN CONSTANT-ELASTICITY COMMODITY MODELS

Arrow and Hahn (*4*, p. 234) have shown that a unique solution is guaranteed if the matrix of partial derivatives with respect to prices $B(P_O, X)$ has a dominant diagonal for every conceivable set of commodity prices. A dominant diagonal matrix can be defined as:

$$\underset{i=j}{|b_{ij}|}\, d_j > \sum_{\substack{j=1 \\ i\neq j}}^{N} |b_{ij}|\, d_j \quad i = 1,2,\ldots\ldots, N \qquad (5)$$

where i's indicate rows, j's indicate columns, b's are matrix elements, and d's represent a set of positive numbers (*12*, p. 311). It is shown below that one can guaran-

[3] If equilibrium quantities are desired, they can be found by substituting the solution (equilibrium) prices into the commodity supply or demand equations.

[4] This method has been widely used in economics to solve nonlinear models (*1, 2, 3, 8, 14*).

[5] As with linear commodity models, the levels of the exogenous variables determine the equilibrium price vectors. For nonlinear models, a set of values for the exogenous variables may determine more than one solution vector.

tee this kind of matrix and, hence, unique solutions for constant-elasticity commodity models.

Each element in the matrix of first partial derivatives (matrix B in equation (3)) is calculated by equation (6) in the constant-elasticity case:

$$b_{ij} = \frac{\partial \mathrm{EXD}_i}{\partial \mathrm{P}_j} = \left[(\mathrm{E.D.}_{ij})\,(d_i) - (\mathrm{E.S.}_{ij})\,(s_i) \right] \Big/ \mathrm{P}_j \qquad (6)$$

where:

EXD_i = excess demand equation for commodity i;
P_j = price of commodity j;
$\mathrm{E.D.}_{ij}$ = demand elasticity of commodity i with respect to price of commodity j;
$\mathrm{E.S.}_{ij}$ = supply elasticity of commodity i with respect to price of commodity j;
di = quantity of commodity i demanded; and
si = quantity of commodity i supplied.

The restrictions of weak gross substitutability (WGS) and degree zero homogeneity can be used to help insure that equation (6) will always produce a dominant diagonal matrix. WGS (*4*, p. 227) is defined by inequality (1):

$$\frac{\partial \mathrm{EXD}}{\partial \mathrm{P}_j} \geqslant 0,\ i \neq j \text{ and } \frac{\partial \mathrm{EXD}_i}{\partial \mathrm{P}_j} < 0\ \ i = j \qquad (1)$$

This assumption excludes complementary price relationships. Because the demand and supply equations have constant elasticities, the homogeneity condition is guaranteed by assuring that:

$$\sum_{j=1}^{N+1} \mathrm{E.D.}_{ij} + \mathrm{E.I.}_i = 0 \text{ and}$$

$$\sum_{j=1}^{N+1} \mathrm{E.S.}_{ij} = 0,\ i = 1, 2, \ldots\ldots, \mathrm{N} \qquad (7)$$

where E.I., i is the income elasticity of demand for commodity i. ($\mathrm{E.D.}_{ij}$ and $\mathrm{E.S.}_{ij}$ are as defined in equation 6.)[6] The homogeneity restriction was imposed by Brandow (*6*, p. 13) and by George and King (*9*, p. 8) on their demand equations in this manner.

Inequalities (2) through (5) show how a dominant diagonal matrix can be guaranteed. First, inequality (2)

$$\left| \mathrm{E.S.}_{\substack{ij \\ i=j}} \right| > \sum_{\substack{j=1 \\ i \neq j}}^{N} \left| \mathrm{E.S.}_{ij} \right| \quad i = 1, 2, \ldots\ldots, \mathrm{N} \qquad (2)$$

[6] See footnote 2 for an explanation of the Nth + 1 commodity.

is guaranteed by WGS and degree zero homogeneity. Also, inequality (3)

$$\left| \mathrm{E.D.}_{\substack{ij \\ i=j}} \right| > \sum_{\substack{j=1 \\ i \neq j}}^{N} \left| \mathrm{E.D.}_{ij} \right| \quad i = 1, 2, \ldots\ldots, \mathrm{N} \qquad (3)$$

is guaranteed by these two restrictions, if income elasticities are not negative. Negative income elasticities do not pose a problem for food commodity models. For example, George and King (*9*, p. 51) and Brandow (*6*, p. 17) have only one negative income elasticity among 49 and 24 food commodities, respectively.

Inequality (4)

$$\left| \underset{i=j}{\mathrm{E.D.}_{ij} - \mathrm{E.S.}_{ij}} \right| > \left| \sum_{\substack{j=1 \\ i \neq j}}^{N} (\mathrm{E.D.}_{ij} - \mathrm{E.S.}_{ij}) \right| \qquad (4)$$

is guaranteed by inequalities (2) and (3). Also, inequality (5)

$$\left| \underset{i=j}{\mathrm{E.D.}_{ij} d_i - \mathrm{E.S.}_{ij} s_i} \right| > \left| \sum_{\substack{j=1 \\ i \neq j}}^{N} (\mathrm{E.D.}_{ij} d_i - \mathrm{E.S.}_{ij} s_i) \right| \qquad (5)$$

is, in turn, guaranteed by inequality (4).

The left-hand side of inequality (5) is equal to the absolute value of the numerator in equation (6), when $i=j$ (that is, the numerator for a diagonal element in the B matrix). The right-hand side of inequality (5) is equal to the summation of the absolute values of the numerators in equation (6) over j from 1 to N, excluding $i=j$ (that is, the sum of the absolute values of the N-1 off-diagonal numerators for the same row in the B matrix).

If the B matrix is post-multiplied by a diagonalized matrix of the prices used in its calculation (that is, the diagonalized matrix of p_j's in equation (6) which correspond to the d's in equation (5)), inequality (5) is guaranteed for all i's. Thus, the requirement for a dominant diagonal matrix is fulfilled. Consequently, uniqueness is assured.

Demand, supply, or both may be divided into components without reversing inequality (5) and, consequently, without destroying the guarantee for a dominant diagonal matrix. For example, in the commodity projections component of the NIRAP model, demand is divided into food demand, feed demand for livestock, export demand, and other use demand; and supply is divided into U.S. supply and imports.

CONCLUDING REMARKS

The impetus for this article came from the need to determine how to guarantee unique equilibrium solutions in the commodity projections component of the NIRAP model. This component is used to make equi-

librium projections of commodity prices and quantities under alternative scenarios that include prespecified levels of the required exogenous variables. The component model is also used in a comparative static manner to evaluate the effects of changing the level(s) of only one or several related exogenous variables (for example, see *13*). Unique solutions in both of these uses are necessary for unambiguous projections; that is, projections that can always be duplicated.

Other procedures may be needed to prove uniqueness for nonlinear commodity models specified with different equation forms. A number of other sufficient conditions for guaranteeing uniqueness can be found in the literature on general equilibrium theory (in *4*, for example). Perhaps some of these sufficient conditions can be fulfilled in other nonlinear commodity models, which would thereby guarantee unique solutions.

REFERENCES

(1) Allingham, Michael G. "Tatonnement Stability: An Econometric Approach." *Econometrica*, Vol. 40, No. 1, Jan. 1972.

(2) ____________ *Equilibrium and Disequilibrium: A Quantitative Analysis of Economic Interaction.* Ballinger Publ. Co., Cambridge, Mass., 1973.

(3) Alm, Hans, Jack Duloy, and Odd Gulbrandsen. *Agricultural Prices and the World Food Economy.* Inst. for Econ. and Statistics, Tech. Bul. 750 07, Uppsala, Sweden, Mar. 1969.

(4) Arrow, Kenneth J. and F. Hahn. *General Competitive Analysis.* Holden Day Inc., San. Francisco, Calif., 1972.

(5) Boutwell, Wayne, and others. "Comprehensive Forecasting and Projection Models in the Economic Research Service." *Agr. Econ. Res.* Vol. 28, No. 2, April 1976.

(6) Brandow, George E. *Interrelations Among Demands for Farm Products and Implications for Control of Market Supply.* Agr. Expt. Sta., Penn. State Univ., University Park, Pa., Bul. 680, Aug. 1961.

(7) Dorfman, Robert, Paul Samuelson, and Robert Solow. *Linear Programming and Economic Analysis.* McGraw-Hill Book Co., New York, 1958.

(8) Edwards, Clark. "Non-Linear Programming and Non-Linear Regression Procedures." *J. Farm Econ.*, Vol. XLIV, No. 1, Feb. 1962.

(9) George, P. S. and G. A. King. *Consumer Demand for Food Commodities in the United States with Projections for 1980.* Giannini Found. Calif. Agr. Expt. Sta., Monograph 26, Berkeley, Calif., Mar. 1971.

(10) Heien, Dale, Jim Matthews, and Abner Womack. "A Methods Note on the Gauss-Seidel Algorithm for Solving Econometric Models." *Agr. Econ. Res.*, Vol. 25, No. 3, July 1973.

(11) Henderson, James M. and Richard E. Quandt. *Microeconomic Theory: A Mathematical Approach.* McGraw-Hill Book Co., New York, 2d Edit., 1971.

(12) Lancaster, Lelvin. *Mathematical Economics.* Macmillan Co., New York, 1968.

(13) Quance, Leroy and others. *Food and Agriculture.* To be published by Resources for the Future, Inc. Washington, D.C.

(14) United Nations. Food and Agriculture Organization. *A World Price Equilibrium Model.* General Commodity Analysis Group, projections res. working paper 3, Project CCP 71/20, Rome, Italy, Nov. 1971.

RESEARCH REVIEW

IN THIS ISSUE

Economists tend to sacrifice far too much relevance in their pursuit of ever increasing rigor, according to Robert A. Gordon in his 1975 presidential address to the American Economics Association. This view tends to attract more support than Gordon was seeking from those with an antimathematics or antiquantitative bias. Gordon clearly is not objecting to rigor. Rather, he is asking for added effort to combine rigor with relevance. He cites economics as the most "scientific" of the social sciences, in part because it uses mathematically formulated theories and econometric techniques. He is telling us to keep an eye focused on relevant social questions to which to apply our science. He warns of traps such as: choosing to work only on social problems that fit existing models; and spending more time sharpening our analytical tools than the tools are worth.

All this is prologue to noting that the three articles in this issue explore ways to become more rigorous. The direct social relevance is not dwelt on in the articles, but it is implied by the authors' concern to sharpen the tools used in ERS for forecasting, explaining, and analyzing market prices and quantities.

Authors of the first article inquire into possible pitfalls following from an assumption, implicit in most input-output analyses, of constant relative prices. One alternative is to consider the dual as opposed to the conventional, primal I/O model. The primal model assumes a list of final demands and seeks interindustry quantities, given constant prices. The dual assumes a list of values added and seeks interindustry prices, given constant quantities. The authors use a different approach which makes prices as well as quantities explicit throughout the model; they follow an autonomous change in price through the system similarly to the way an autonomous change in quantity is ordinarily followed.

Authors of the second article compare an econometric model published in 1973 in *Agricultural Economics Research* with subsequent trends. They close with the observation that a simple, lagged forecasting equation tracked the violent price changes of the early 1970's better than the model with its six simultaneous equations. But before seeing this finding as an argument for a less rigorous model, recall that simultaneous equation models carry, in addition to forecasts, the burden of explaining why prices move as they do and also of pointing to ameliorative policies.

The nature of this article raises questions of concern to readers of this journal, questions which apply to all econometric models, not just the one used as an illustration. The fact that users might critique an author's model after it has been published in a journal raises questions about the responsibilities of the author, the reader, and the journal editor. These responsibilities relate to the purpose of the model and the types of problems to which it will or won't be relevant, to conformance of the model to theory, to validation and empirical content, to extrapolation into unvalidated applications, to the importance of judgment in interpreting the results, and to the accuracy of reporting what was done.

Finally, the computer has changed the way economists look at things. New algorithms on large computers display solutions to nonlinear systems at nominal cost. A few years ago, a mathematician would have found it difficult merely to prove that a solution exists to some models now in use, much less find a way to display it. Using the new capability, the author of the third article shows that sufficient conditions for a unique solution to a nonlinear econometric model of competitive markets can be met with certain not too restrictive assumptions.

Clark Edwards

Note: We regret that an error appeared in the article entitled: "Measuring Labor Productivity in Production of Food for Personal Consumption," by Eric C. Howe, Gerald E. Schluter, and Charles R. Handy, published in the October 1976 issue of this Journal. In table 6, p. 127, the unit designation "Million dollars" should have been "Thousands of persons engaged."

THE HUMAN ECONOMY

By Eli Ginzberg. McGraw-Hill Book Company, New York. 274 pages, 1976. $11.00.

Economists frequently study factor input relationships in the context of a competitive market model. This approach is applied to labor and nonlabor inputs alike. Professor Ginzberg argues convincingly in *The Human Economy* that the assumptions of the competitive market model are too restrictive for analysis of employment relationships. His conclusions are based on analysis of the characteristics of inert nonlabor inputs compared with those of labor. He sees nonlabor inputs as totally inactive in a transaction. The owners of inputs care little as to how they are used once the transaction is completed. For these inputs, price is a good indicator of supply and demand, and it is valid to assume that inputs of a kind are homogeneous, within an acceptable range, for production purposes.

In contrast, people are active participants in a transaction which involves them as workers. Most consider employment as a long-term affiliation leading to higher earnings, fringe benefits, job security, and work satisfaction, instead of a simple exchange of labor for wages. Moreover, while the supply of workers is influenced by price (wage), workers' decisions to enter a particular job market are also influenced by past experience and training, options, and expectations on and off the job. In addition, labor performed on a given job by different workers is not necessarily homogeneous. Workers doing the same work and receiving the same wages often have

different interests and motivations which translate into different productivity levels.

The author calls for a new theoretical framework to analyze the multiple dimensions of human behavior with respect to the economy. In working toward this end, he explores ways and means through which people gain skills and acquire education and training. He also examines how these processes are influenced by societal values, large employers, labor unions, educational institutions, and government. In developing his thesis, the author draws primarily on the historical experience of the United States and Western Europe. Occasionally, he looks at the manpower situation in some of the developing countries to see if the experiences in the developed nations may be applicable. He also contrasts the manpower situation in Russia with that in the developed Western nations.

Professor Ginzberg's arguments against using the traditional or commodity approach for analyzing manpower situations have considerable merit. In addition his thoughtful discussion of a human resource approach to the study of the economy is enlightening. However, he stops short of developing a formal model or schema to replace the market model for expressing relationships concerning the processes involved in skill acquisition and manpower utilization. Notwithstanding his instructive presentation, I came away with the nagging question as to how each of his many excellent observations tie together into an operational model for research purposes. Despite this shortcoming, this book is a significant contribution to human resources literature, for it contains components, or building blocks, for the development of a theory of manpower utilization. Most people engaged in research or policy work involving employment and manpower should find this work very useful.

The book is also well organized and well written. In part I, differences between human and nonhuman resources are presented, followed by a discussion of the consequences of the differences for theory development. Next, the manpower development system, comprised of the family, formal educational institutions, on-the-job training and work experience, is outlined. Emphasis is given to interactions between this system and societal value structures, government and other institutions, and the economy. In part II, the author discusses the means by which people acquire skills and education. Emphasis is placed on the family, school, and employing organization as critical institutions in skill development and as determinants of manpower utilization.

In part III, the author identifies factors instrumental in influencing skill development and employment and income opportunities for the population. Primary emphasis is placed on the strength and capacity of the economy to provide opportunities. He contends that the number and kind of jobs the economy creates determine to a large extent skill development, as few people would spend the time and effort in preparation for positions which do not exist. However, the author explains that government, schools and training institutions, and societal values also affect manpower development and use. He discusses how income and employment opportunities are segmented among groups in a society, and the imbalances between groups that characterize skill development and opportunities in developed and developing economies.

Part IV is devoted to explaining the conflicts and compromises of employees and managers of firms as each work toward their individually determined goals.

Part V concludes with a discussion of parameters for a manpower policy. The objectives of this policy are to expand the options of citizens to develop their potentials, and to use them in a meaningful, productive way.

Robert Coltrane
Manpower Studies
Economic Development Division

ENCYCLOPEDIA OF AMERICAN AGRICULTURAL HISTORY

By Edward L. Schapsmeier and Frederick H. Schapsmeier. Greenwood Press, Westport, Conn. 06880. 467 pages. 1975. $25.00.

If you have ever wondered where you could find simple, reasonably useful definitions and descriptions of events, persons, or institutions relating to agriculture, beginning with "Aberdeen-Angus Journal," and ending with "zanjero," then this is your book. The volume includes brief biographies of farm leaders, editors, inventors, and others. The entries, which are arranged alphabetically, are supplemented in many instances with citations to books on the person or topic.

The value of the volume is enhanced by a series of topical indexes and a general index which picks up names and subjects not listed separately in the text. For example, the text contains a paragraph on "frozen food." Clarence Birdseye is mentioned, and his name appears in the general index.

The authors cover a wide range of subjects. In most cases, the information is either adequate or will lead the user to additional sources. I have noted only one substantial error—there was no "Agriculture Act of 1973." The material discussed under that heading belongs under the heading "Agriculture and Consumer Protection Act of 1973." It looks as if some galleys were not in order.

This book will be of value to any agricultural economist, historian, or writer who needs a ready reference to past events and persons. The authors are to be congratulated for their contribution.

Wayne D. Rasmussen
Leader, Agricultural History Group
National Economic Analysis Division

MEASURING ECONOMIC AND SOCIAL PERFORMANCE: NEW THEORY, NEW METHODS, NEW DATA

To measure the performance of any *social* organization, community, or society, we need direct counterparts of the quantities, prices, and values required to measure *economic* performance. However, before I discuss the problems of conceptualizing and measuring these quantities, prices, and values, I will cover three other topics.

First, the quantity, price, and value measures developed for U.S. agriculture and closely related sectors during 1922-53 by the former Bureau of Agricultural Economics exemplify good analysts applying good theory to good data and making cumulative improvements in measurement and understanding. From the twenties to early in the fifties, at least, the U.S. food and agricultural sectors were better supplied with economic data and analysis than any other sectors of the U.S. economy—better perhaps than the corresponding sectors of any other economy.

Second, the revolution in economic theory and econometrics in the thirties and forties led to the creation of national income and product accounts. This revolution depended on theoretical developments, particularly by John Maynard Keynes and Wassily Leontief. Efforts of "measurement without theory" helped describe problems but did not explain them or point to remedies.

Third, the current revolution in sociometrics is bringing sociologists and economists closer together and it may lead to a new synthesis of concepts, methods, and data covering the social system as a whole. The "social indicators" movement emerged about a decade ago. The movement was associated with two others: the "accountability" movement that hit public universities in the midsixties and the Programing-Planning-Budgeting System movement in the Federal Government (1965-68) which required each agency to define its program elements and objectives and identify the resources used to promote each objective. In both movements, the traditional methods of resource allocation in nonmarket institutions were attacked.

My objective for an operational system of social indicators and social theory is to explore the feasibility of implementing a system of accounts, in dollars, which would include the national income accounts and add up to a gross social product (GSP) much larger than and including the gross national product (GNP). Dollar values would be attached to all outputs from the social system to individuals, and to all inputs from individuals. The dollar value of total rewards to individuals (GSP) would equal the dollar value of total contributions by individuals (the gross social income).

This objective requires a definition of an exhaustive set of rewards, a unit for measuring the quantity of each kind of reward, and a method for assigning prices to each kind of reward. The same types of information would be required for contributions.

Social accounts require a complete accounting for *time*. Time spent in household production is a major component; time spent in school is another. Time at work (producing GNP) and time asleep are others. The rest of the day is the fifth component. People allocate their time (24 hours a day) among behavior settings which collectively define their lifestyles; simultaneously, they allocate their money (personal consumption expenditures) among these settings.

Besides the money circulated in the economy, each person has an endowment of resources or capacities which can be used as inputs or contributions to the social system. These capacities may be clustered into five groups. The first three groups are personal: health (physical, emotional, and mental), skills (work related and others), and value commitments and character. Capacities in the fourth group are socially validated in the sense that they reflect the individual's evaluation by others: power in formal organizations (backed by written job descriptions); prestige; and political power. The fifth group includes rights to income from property and transfer payments, which again must be socially validated.

The result is a model in which each person seeks to maximize utility by choosing an optimal lifestyle subject to the constraints imposed by personal endowment. In general, people know about how much of each resource they must put into a behavior setting for each hour of occupancy and about how much of each kind of reward they will receive from it. They spend the resources available to them in the course of allocating their time among behavior settings. When the person maximizes utility by choosing an optimal lifestyle, a shadow price or marginal utility is associated with each resource in that person's endowment. Since one of these resources is money income, the marginal utility of an additional unit of each other resource may be compared to the marginal utility of an additional dollar of money income. In other words, the marginal utilities of other resources can, in principle, be translated into dollar equivalents. When these dollar equivalents are multiplied by the corresponding resource quantities, we can obtain estimates of the contributions of each resource to the individual's "total income," which, like the specific resource contributions, would be expressed in dollars. In my complete paper, I give several examples of how to make this model operational.

A data system based on this approach need not intrude significantly on individual privacy. The time series data required could be based largely on sample surveys of *behavior settings* rather than of individuals. A behavior setting is equivalent to a small establishment or firm. In measuring the characteristics of a behavior setting, it would not be necessary to identify the particular persons within it. And, in basing national accounts on samples of establishments and other behavior settings, it would not be necessary to reveal the identities of individual establishments. In addition, rather small sample surveys of the use of time by persons and households could be used to assess the validity of the basic series derived from surveys of behavior settings.

This note summarizes the ERS Bicentennial Lecture delivered by Karl A. Fox on June 22, 1976. Dr. Fox is a professor of economics at Iowa State University.

APPRAISING THE ECONOMIC PERFORMANCE OF THE FOOD INDUSTRY

Questions asked by consumers, farmers, political leaders, and others about food prices during recent years amount to a demand for comprehensive information about the economic performance of the vast industry that processes and distributes the Nation's food. Appraisal of the industry's performance is important not only for the usual reason that it is a necessary step for improving performance. Beset by inflation, much higher real costs of energy, increased competition from abroad for food supplies, and basic environmental

problems, the public is prone to attribute disliked consequences to apparently simple causes that have correspondingly simple solutions. Excessive profits, inefficiency, and other presumed faults of particular industries are high on the list of such causes. Solid evidence on industry performance would help to sort out industry-specific deficiencies from broader difficulties requiring economy-wide approaches for effective solution.

Nine elements of performance seem applicable to the food industry. First is *product presentation to buyers*, which includes not only the variety, healthfulness, and packaging of foods but also objective information useful to buyers (especially to consumers). *Efficiency* and *progressiveness* are familiar criteria for performance. The level of *selling costs* is considered an important if controversial element. *Returns to factors of production* include not only profits of firms but also salaries, wages, and fringe benefits of management and labor. *Stability* of prices and output is an element to the extent that instability arises within an industry rather than being forced upon it. *Fair conduct* includes observance by firms, labor unions, government inspectors, and others of ethical standards generally accepted as proper conduct by private individuals. *Price coordination* has to do with price relationships that efficiently coordinate the industry internally as well as with consumers, farmers, and other economic groups with which the industry interfaces. The familiar element of *externalities* completes the list: socially significant costs and benefits not directly or indirectly considered by industry decisionmakers ordinarily cause performance to be less satisfactory than is possible.

Three types of problems are encountered in appraising performance of any industry. One is the formidable task of setting performance standards, and of identifying and measuring departures from these standards. The second problem is obtaining the funds, time, and access to data necessary for the work. The third is obtaining consistent political support for comprehensive performance appraisal and for the apparently necessary modifications of functions of some Government agencies. I discuss the first type of problem on the assumption that the other two are somehow solved.

The market provides only an approximation of the types of foods that would be most satisfying to consumers, in part because of buyers' lack of information and of sellers' efforts to influence their purchases. To appraise *product presentation to buyers*, it seems possible to make objective tests of quality and taste characteristics of many foods, to ascertain price differentials at which various qualities and brands are offered, and to learn the state of consumers' information about the choices. These findings can be put together to identify instances in which consumers' purchasing behavior differs from what it would be had they full information.

The *efficiency* of processes, plant operations, alternative market channels, and vertical coordination in the food system can be studied to identify potential cost savings. Reasons for inefficiencies may be traceable to firms' decisions, to circumstances insisted upon by labor unions, or to Government regulations. Whether equity or other considerations warrant a given loss of efficiency is a value judgment, but the loss of efficiency can at least be evaluated. Also important is the question of whether the costs of inefficiency are borne by the firm involved or passed on to the public.

To cut through the tangle of claims and counterclaims about *selling costs*, my proposal is that food retailers' advertising expenditures of more than a half of 1 percent of sales, and all give-aways, be considered excessive, together with all food processor advertising of more than 3 percent of sales for any class of product. Using such a standard would be better than coming to no conclusion for lack of a standard, and the burden of proof about the social usefulness of selling costs would be shifted to those who favor higher costs. The excess costs of some marketing strategies apparently are not limited to advertising but also include much personal selling and some packaging, transportation, and warehousing expenses; the whole bundle should be studied.

Confusion about *returns to factors of production* and their relation to prices is so great that here, too, a necessarily semi-arbitrary standard should be adopted. The proposed standard for profit rates applies to average after-tax profit as a percentage of net worth over 3 years in any branch of the industry. The interest rate on Government bonds plus 3 percent is taken as a reasonable rate. The standards for salaries, wages, and fringes are rates generally paid in comparable industries. This approach implies that questions about the spread between compensation for workers and managers, and about the strong tendency of wages to rise faster than productivity, are to be regarded as economy-wide rather than industry-specific questions.

Appraising *price coordination* involves study of lags among farm, wholesale, and retail prices and also of price seasonality and price differentials for location and quality. Lags that might be reduced, and price differentials inconsistent with underlying costs or with supply and demand conditions, represent poor performance. Appraisal of average amounts of farm-retail price spreads will emerge from appraisals of efficiency, rates of return to factors of production, and selling costs. Comments about appraising *progressiveness*, *stability*, *fairness of conduct*, and *externalities* appear in the larger paper this article summarizes.

Thorough appraisal of food industry performance would be a continuing task and, if done, probably would be a part of a larger effort to appraise performance in several leading industrial sectors. More resources and more access to data than is now available would be required. The missions, powers, and competencies of the various agencies that might be involved in the work would give each agency certain comparative advantages in making particular types of studies.

The importance of understanding industrial performance and its determinants warrants a new role for the Federal Trade Commission, one that might justify shifting its other functions to other agencies. The new function would be continuous appraisal of the performance of American industry and of the quality of competition. Data collection and publication would be a major function; so would studies to appraise and explain performance. The U.S. Department of Agriculture's major contribution to appraisal of food industry performance might be in the areas of efficiency, progressiveness, and price coordination, although no agency would be limited to specific areas. A consumer agency might take on

matters relating to product presentation. Economists in universities would continue their research on performance and its determinants, and would have far better data to work with. Other Federal Departments, the President's Council of Economic Advisors, the Joint Economic Committee and some other committees of the Congress, and organized consumer, farmer, industry, and labor groups would use the information and perhaps add to it. Special studies, such as that of the Food Commission in the midsixties, would not be necessary if appraisal of industry performance were a continuing activity.

This note summarizes the ERS Bicentennial Lecture delivered by George E. Brandow on September 8, 1976. Dr. Brandow is a professor of agricultural economics in the Department of Agricultural Economics and Rural Sociology at Pennsylvania State University.

AMERICAN FARM POLICY 1948-1973

By Willard W. Cochrane and Mary E. Ryan. University of Minnesota Press, Minneapolis, 431 pages. $18.50.

The authors call their work a reference book in which they record as accurately as possible farm policy of the United States from 1948 to 1973. But it is more than a reference book. It includes much of Dr. Cochrane's philosophy relating to interpretations of economic developments, the general conclusions about program benefits and costs, and principles to guide policy formulation. Accordingly, much of the book is interesting reading and most timely for the inevitable upcoming debate on farm policy legislation. If your interests run in this general vein, I strongly recommend the book, especially the interpretations in part I and the appraisals in part III.

One of the more interesting conclusions of the book, and a surprising one for me, is an implied or perhaps unintentionally strong criticism on economic grounds of farm policy of the period. The authors make some persuasive arguments against programs as they discuss resource use, changes in the size structure of farms, the plight of small farmers and laborers, land values, high production costs, and reduced foreign trade. Further, they discuss the issues of who benefited from the programs—including returns to the large commercial operators, food supplies and prices, pollution, and so forth.

Early in the book, the authors tell the readers they must understand the agroeconomic conditions of the post-World War II period to rationalize farm policy of the period. "It was a highly dynamic period, a wonderously productive period, but most often an economically painful period for farmers" (p. 3).[1] This characterization is largely true, but plausible alternative interpretations may raise doubts about the rationalization of farm policy. Indeed, in the final pages of the book, the authors suggest their appraisal may be little more than the judgment of two observers. They comment that " . . . certainly the appraisal is dependent to a large degree on our particular value systems" (p. 391).

The conclusion that the period was " . . . wonderously productive" is a theme that threads throughout the book. Productivity seems to be considered largely "new technology," an argument quite basic to the authors' rationalization of farm policy. Much of what they refer to generally as technology springing from " . . . the high value that American Society placed on scientific research and technological development" really resulted from shifts in resource use and the changing size structure of farms.

Certainly productivity measured by yield per acre or output per person or per farm overstates, perhaps grossly, the productivity advance on individual farms. The very rapid change in size structure of farming—creating large efficient units by gobbling up small inefficient ones— could contribute a major part of the productivity advance in farming as a whole yet little improve the basic productivity of the large, efficient farm unit.[2] I am not asserting that no basic improvement occurred in farm productivity; that would be wrong and bordering on heresy. But I do suggest that the advance was probably more similar to advances in other industries.

Thus, much of the uptrend in farm productivity for all farms resulted from resource shifts and changes in the size structure of farming, both of which received great impetus by price insurance and other facets of the policies of the period. The authors develop these issues when they discuss resource shifts and the forces influencing the size structure of farming. They do not seem to come full circle to sufficiently question their basic rationalization of farm programs. But they come very close in the final chapter of the book.

Some very damaging criticism of farm programs appears, it seems to me, in the discussion of changes in the size structure of farms. The authors effectively explain how price and income insurance, provided by support programs, made it easy for " . . . the alert, aggressive farmer to invest, reduce costs, expand, increase his rate of return, and expand further." "The alert and strong cannibalized the less adaptable and weak." This issue has been neglected in the literature, both from the standpoints of data and of analyses. Free markets or even programs providing a lower level of support probably would have slowed these shifts, eased related adjustments, and might have reduced the chronic excess resources and overproduction in agriculture.

The authors effectively use many studies which suggest that big adjustments would have been necessary to shift to the "free market." They conclude: "The price-income consequences of the free-market solution were too terrible to contemplate." Surely, given the state of agriculture in the midfifties and early in the sixties, analysts would agree that big declines in farm prices and incomes would have resulted from a return to free markets. The authors cite studies and analyses by Ray-Heady and Nelson (p. 362) which suggest that free markets would have resulted in extended periods of severely depressed farm prices and incomes as well as much wider variability in prices and incomes. Still, Cochrane and Ryan's case for farm programs is not all that convincing.

[1] Page numbers in parentheses refer to the Cochrane-Ryan book.

[2] Implications of Changes (Structural and Market) on Farm Management Research, CAED Report No. 29, Iowa State University, 1967, pp. 114-117.

Continuing their argument, the authors point out that 2.85 million farms went out of business between 1949 and 1969 because net returns were too small to enable these operators to stay in business. They point out too that the assets of these farms " . . . were gobbled up by those alert aggressive farmers . . ." who used the price and income insurance provided by farm programs to invest and expand efficient operations as well as increase the number of larger efficient units. These larger farms (size classes I, II, and III with receipts of more than $10,000) prospered quite well indeed. They increased in number from about 0.5 million units in 1949 to almost 1.4 million by 1974. These larger farms in 1974 accounted for 95 percent of total farm output and 80 to 85 percent of total assets and labor resources used in agriculture. These are the farms that make up U.S. commercial agriculture; these are the main benefactors of farm programs.

The authors are persuasive in their development of a long list of shortcomings and social costs of farm programs. One wonders, then, how they concluded that " . . . the gains to society . . . in protecting vital interests of producers and consumers outweigh the real costs to society " (p. 391). Further, "it must be concluded that the operation of government programs of price and income support . . . benefited the alert and strong at the expense of the small and the weak" (p. 266). They do recognize that these improvements came at great cost in maladjusted resources, rural-urban adjustments, a high production cost structure in agriculture, and possibly even aggravated pollution problems (p. 387). The authors also recognize the cost to the American taxpayer in higher prices for food as well as transfer payments flowing from taxpayers to commercial farmers and agribusiness firms. "But to all it was a burden, and the total burden for the 26-year period was large indeed." " . . . U.S. taxpayers paid on the average $3.7 billion per year to support farm prices and incomes from 1948 to and including 1973. What more is there to say?" (p. 391).

It is understandable that the authors seem to struggle to rationalize their general conclusion justifying the social costs. They point out the advantages of greater stability, increased equity to farmers, and abundant food supplies. But they still wonder: "Is there not a firmer foundation for the appraisal? We think there is" (p. 391). And their firmer foundation is that the Congress in its wisdom " . . . reaffirmed year after year the need for price and income programs to protect and support farm incomes" (pp. 384-386).

Surely the book raises questions as to how it might have been if market incentives had slowed resource adjustment, the rapid pace of change in size structure of farms, the shift to purchased energy and other nonfarm inputs, and the rise in total farm output. I doubt if even the most astute econometrician could recapture and measure forces in the past accurately enough to simulate what might have been. But the alternative scenario deserves serious thought in looking toward agricultural policy in the next 5 to 10 years.

The agroeconomic setting in U.S. agriculture today does not rest heavily on farm programs, although farm programs remain on the books. Moreover, coming years may bring generally tighter worldwide demand-supply balance for farm products. But this balance, the authors agree, will vary from year to year and it could lead to wide fluctuations in farm prices and incomes in a free-market policy for agriculture. Accordingly, they conclude that " . . . the Agriculture and Consumer Protection Act of 1973 will not be permitted to expire in 1977." It will be " . . . refined by the Congress, with or without guidance from the administration, and new legislation will be passed designed to protect the vital interests of farm producers and consumers with regard to food" (p. 396).

The book ends with guiding principles for the formulation and development of new programs. Cochrane and Ryan recommend a reserve stock program, regulation of exports, and supply management. Programs should be highly flexible and prices stabilized near world price levels. Income assistance should be in the form of direct payments to producers for specifically designed purposes. Also proposed are food assistance programs for domestic consumers as well as foreign food aid.

After years of exposure to the technical aspects of farm policy development and farm program evaluation, I am prompted to make these related observations. First, bureaucracies, in Government and private industry, are notoriously inefficient in attempting to make market decisions. Second, economists and statisticians can provide insights into what is happening as well as likely near-term developments, but they are notoriously conservative in trying to identify and measure longer run forces, including economic and political forces, that will shape agriculture. And third, there always exists in our society an intelligentsia or a bureaucracy too willing to assume responsibility for market decisions and quite willing to decide what is best for you and me. I hope we will be wise enough in formulating future farm policy to recognize our limitations, the basic economic and political forces on the market, and the need for minimum and largely automatic administrative interventions in the market.

Rex F. Daly
Outlook and Situation Officer
Office of Administrator

ECONOMICS OF THE PRODUCT MARKETS OF AGRICULTURE

Harold F. Breimyer. Iowa State University Press, 1976. 208 pp.

Those who have known Professor Breimyer and his work over the years anticipate that his writings will be scholarly, concise, and sprinkled with succinct conclusions and summaries. This small book, *Economics of the Product Markets of Agriculture*, carries on this enviable tradition. Substantive marketing analysis and thought seem to have sharply declined since the exciting post-war period of the fifties and early sixties. This volume counters the decline and will be a useful addition to any marketing professor's library.

The book can be sorted into three parts. The first four chapters provide capsule summaries of basic marketing concepts and analytical ideas. Chapter 5, "Dimen-

sions and Structure of the Marketing System for Farm Products in the United States," brings together data and summary evidence of costs, marketing structure, and pricing practices as they currently exist. The final four chapters consist of summary essays on marketing research, Government policies, transportation, location, and economic development.

Breimyer identifies on page 166 the "theme that emerges at various points in this book. It is that the cost structure of nearly all modern industry, including the processing and distribution of farm products offers opportunity for discriminatory pricing." A further theme would seem to be the evolution and dynamics of interacting forces. The situation is very seldom clear-cut or stable.

Brevity is not prevalent among economists! However, here is a book in which one wishes for additional discussion and illumination from a scholar who obviously has much more to say. One longs to be a student in the several hours of lecture discussion which obviously must surround one of Professor Breimyer's chapters! Breimyer pulls his thoughts and ideas from a truly amazing breadth of scholarship. The source references are a major contribution. However, brevity often results more in name-dropping than in a meaningful identification of the position or idea of the author referred to. Also, the book contains a practice I thoroughly dislike—all references are neatly catalogued by chapter at the back of the book. I greatly prefer having the footnote on the same page as the reference so that the exact nature of the source referred to can be noted easily.

The publisher's advertising release presents the book as designed to fit a traditional course in agricultural economics. In his preface, Breimyer says the book is written as a text. Certainly teachers of marketing will find it of great use. If it is used as a course text, a preceding course which thoroughly grounds the student in the detail of what happens in today's marketing system must be presumed.

Finally, the author states: "the language is traditional-verbal, not mathematical." This reader is grateful that this is true. It is refreshing to receive the communication of stimulating ideas from a craftsman who can creatively use the language in other ways than as footnotes to tables, graphs, and computer printouts!

Richard L. Kohls
Dean of Agriculture
Purdue University

WORLD FOOD PROBLEMS AND U.S. AGRICULTURE

The period since mid-1972 has been an exciting one for observers of world agriculture. It has been a long while since there were so many changes in so brief a time. Because of the attention given to the food difficulties of the low-income countries and to the wild price gyrations that have affected international markets for agricultural products, one might have expected that some new and feasible initiatives would have been started during these years. To the best of my knowledge, this did not occur.

If a concatenation similar to that of 1972-74 should occur again within the next decade, it is highly probable that similar results would occur. The basic national and international policies remain. Under these policies, very modest deviations in world food supplies resulted in tight food supplies for the developing countries and high, unstable prices internationally.

During the next few years, neither the industrial countries nor the developing countries are likely to consider adequately the problems of increasing food production in the developing world. We are likely to make exactly the same mistakes that were made before.

PER CAPITA FOOD SUPPLIES AND THE DEVELOPING COUNTRIES

Several projections have been made of total and per capita grain production and demand. They indicate that significant effort will be required if production is to match growth in demand. From the standpoint of the developing countries, it is highly likely that during the next 15 years demand will grow substantially faster than output. The difference would have to be made up by imports. It is not that supplies would be unavailable in the rest of the world, but there would be simply no mechanism by which the developing market economies could import 80 or 90 million tons of grain. Aid will not fill more than a small part of the gap. If efforts are made to import the rest, the impact on income growth in the developing countries would be so severe as to dampen the expansion of demand for grain.

Past achievements in agricultural production can be improved upon. Grain yields are low in the developing countries. But they are increasing, and I can see no reasons involving resource or biological considerations as to why grain yields in the developing countries cannot reach and, yes, surpass the yields now obtained in the industrial countries.

Increased resources and improved technology are important for increasing food production in the developing countries. But we have for far too long been silent or talked too softly about the adverse effects of national agricultural and trade policies. The developing countries depend upon agricultural products for a very large percentage of export earnings. One nearly universal feature of such countries is an overvalued currency.

An overvalued currency acts as a tax on exports and a subsidy on imports. Very soon the value of imports exceeds the value of exports, and foreign exchange reserves are exhausted. Consequently, various measures must be used to limit imports. Among the imports that may be limited are those important to increasing agricultural output—fertilizer, pesticides, herbicides. In any case, the decision concerning what should be imported, and on what terms, becomes a political decision rather than one based on the real value of imports.

Other political decisions affect export taxes, import subsidies, and internal price ceilings. These policies dampen domestic prices and benefit consumers, but tend to discourage agricultural production.

It is not clear why governments of developing countries so frequently follow policies that obviously discourage food production, unless it is because the industrial countries provide a model. In the industrial countries, we follow policies that reduce the export earnings of

the developing countries. Almost all of the industrial countries had or have sugar policies that encourage production when costs are high and limit consumption through unnecessarily high retail prices. Industrial countries often pay export subsidies on products that compete with the exports of developing countries. Our tariff structures make it virtually impossible for the developing countries to carry out the first processing of their agricultural and other raw products. We prevent such activity by having a low, perhaps even zero, tariff on the raw product and what may appear to be a very modest tariff on products resulting from the first processing. But the modest tariff on processing may result in protection of 100 percent or more for the processing activity.

INTERNATIONAL GRAIN PRICES AND THE DEVELOPING COUNTRIES

What happens to the general level of international grain prices during the next few years will have a major impact upon U.S. agriculture, agricultural policy, and the food supply of the developing economies. Given the probability that international grain prices might return to real levels not far above those of the early seventies, it seems reasonable to speculate whether the circumstances of the developing countries would improve or worsen.

The developing countries that import grain would have a relatively assured supply at quite low prices. The volume of food aid likely would increase significantly from recent levels, and the foreign exchange outlays required to pay for grain imports would be further reduced. But the net impact on foreign exchange earnings on all developing countries would almost certainly be adverse. Although the net grain trade balance of the developing countries is negative, these countries are net agricultural exporters. Reduced foreign exchange earnings would cut back imports of materials and equipment important for increasing agricultural production.

The indirect effects of low international grain prices could be much more serious than the direct effects in impairing food production growth in the developing countries. Further significant declines in grain prices and the rebuilding of grain reserves would all too likely result in both a false perception of security and a loss of the sense of urgency concerning the numerous changes that are required if per capita food supplies are to grow markedly in the developing countries during this century.

A FOOD AID PROGRAM

My proposal for a food aid program, which I have called a grain insurance program, is a very simple one. To any developing country that participates, the United States would offer to meet all annual grain production shortfalls from trend that exceed a given percentage. The food aid program would replace most existing U.S. efforts, although I would not argue that it should be our only food aid effort—only the major effort. The cost would not be beyond our means. If the United States covered all grain shortfalls of more than 6 percent for each developing country, the average annual payment would be approximately 5 million tons.

The 6-percent criterion is admittedly arbitrary, although not entirely so. The criterion reflects two considerations—the incentive to hold some grain reserves in the developing country and the effect of the insurance payments on local output. If the percentage were very low, say between 1 and 2 percent, there would be no economic incentive for holding reserves. Further, if such departures from trend were met, the magnitude of the grain transfers would be large enough to significantly reduce the average expected returns to the local producers. It would thus limit the growth of domestic grain production.

Many of the developing countries suffer from substantial variability in their grain production. Since grain accounts for as much as 70 percent of the total calories consumed in many developing countries, fluctuations in production cause variations in food consumption. The grain insurance program would provide substantial security. It would permit greater risks to expand food production in the full knowledge that, if there were unexpected adverse production effects, human suffering would be minimized. The program would contribute very little to the longrun problems of inadequate food supplies. But I do not think any food aid program, even a massive one, can contribute to longrun improvement in the food supplies of the poorer people of the world. Such people are going to have better diets only as economic growth occurs and food production expands.

This note summarizes the ERS Bicentennial Lecture delivered by D. Gale Johnson on October 8, 1976. Dr. Johnson is Provost of the University of Chicago and the Eliakim Hastings Moore Distinguished Service Professor of Economics.

INTERPRETING PRICE ELASTICITIES FROM PANEL DATA*

Consumer response to changes in retail price is usually summarized in the form of price elasticities. Although point estimates of elasticities are usually reported by researchers, persons using such information often, at least implicitly, assume a probability distribution around the estimates. Yet choices concerning the method employed or the data source used are usually left, unquestioned, to the discretion of the researcher.

Our research underscores the importance of the statistical model and the data source in the determination of a numerical estimate of price response, and in its ultimate interpretation. Meaningful statements about estimated relative responses to price changes can only be made within the context of the model and the data used.

DATA AND RESEARCH METHODS

More than 1.6 million purchase records of individual dairy products were available from the approximately 7,500 households of the Market Research Corporation

*The research reported on here is based on results from Boehm's unpublished 1974 Ph.D. thesis at Purdue University: *An Econometric Analysis of the Household Demand for Major Dairy Products.* The research project was financed by USDA.

of America (MRCA) National Consumer Panel (NCP).[1] These records include information about product type, price, quantity, size and type of container purchased, and purchase date. Demographic characteristics and socioeconomic status of each household were available.

Both cross-sectional and time series models were developed to obtain estimates of the household response to changes in retail price (*2, 3, 4*).[2] In both models, the problem of regression analysis of pooled cross-sectional and time series data arose (*1, 5, 8, 10*). The cross-sectional model used aggregated purchases for each consuming household as the dependent variable during the entire time period of data availability. Independent variables included the price paid, annual household income, several socioeconomic characteristics, and the age and sex of the household members.

The time series model specified regional per capita consumption as the dependent variable. Observations were generated by aggregating the quantities purchased by all NCP households within an MRCA geographic region for each 2-week period and dividing the results by the regional panel population. Independent variables included the weighted average price paid, average price for substitute and complement products, income, and dummy variables for season and region.

RESULTS

Elasticities were obtained for 32 major dairy products. We focus below on the results for three of them: regular whole milk, 2 percent milk, and a composite product—total fluid milk (see table).

Price elasticity estimates from household panel data for three fluid milk products, 1972-73

Product	Statistical model: Cross-section	Statistical model: Time series
Regular whole milk	−1.7008*	−0.3795*
2 percent milk	−1.3279*	−.5484*
Total fluid milk[1]	−1.6282*	−.1767*

*Indicates that the estimated coefficient was statistically significant at the 10-percent level or better. All estimates were calculated at the mean of the data.

[1] Includes the consumption of regular whole milk, chocolate milk, 1 percent milk, skim milk, 2 percent milk, and buttermilk.

Since both models were linear, point elasticity estimates were calculated at the mean values. In every case, the estimate from the cross-sectional model is more elastic than from the time series model. This result supports the contention that response estimates from cross-sectional models should be seen as longrun responses (*7*, p. 208). However, these approximate longrun responses should be interpreted carefully and with reference only to the model and data base from which they come. For total fluid milk, for example, the number indicates simply that those households using milk and paying 10 percent more than the mean price consumed an average of 16 percent less milk than those paying the mean price, *ceterus paribus*. This indication does not necessarily imply that the demand for milk is elastic. The estimate may suggest the final equilibrium adjustment which would result from a one-time change in price, other things being equal. The fundamental assumption, of course, is that by observing consumers in different circumstances at the same time, one can get information that will help in forecasting the behavior of particular consumers when their circumstances change.

The elasticity estimates obtained from the time series model are quite consistent with previously held expectations and with aggregate market, time series studies (*6, 9*). The estimated price response is highest for 2 percent milk and lowest for the composite product, total fluid milk. A 1-percent increase in the weighted average price during a 2-week period tended to reduce the average 2-week per capita consumption rate by 0.17 percent, *ceterus paribus*. This indicates that total consumption in the aggregate market may change very little in response to a change in the weighted average market price. However, it does not necessarily imply that the demand for milk is inelastic outside of the context of the current model and the data used in it.

CONCLUDING COMMENTS

This research illustrates the importance of model specifications. It may be inappropriate to use the price response estimate from the cross-sectional model and to conclude that increases in the average market price for milk will result in decreases in total revenue for the dairy industry. Likewise, it may be inappropriate to conclude from the time series model that changes in milk price will have little effect on total consumption. Knowing something about how the total market responds to changes in the average price over time tells us nothing about the adjustments which will take place when price changes within a market during a particular time period! Changes in price policy can, and probably will, have both kinds of effects.

In the years since Nerlove's insightful paper in 1958, there has been too little effort in our profession to explore methodologies relating estimates obtained from cross-sectional and time series data systems (*8*). Kuh suggested that, for policy purposes, the numerical difference between the cross-sectional and time series estimates should be ascertained: "If the time series estimate is some function of the typical cross-sectional estimate, one estimate can be translated into the other irrespec-

---

[1] The United Dairy Industry Association (UDIA) acquired these data as a client of the Market Research Corporation of America and made them available to us for research purposes. Dr. G. G. Quackenbush, Director of Economic and Marketing Research of UDIA, was instrumental in getting research using these data started and continues to make contributions as the research progresses.

[2] Italicized numbers in parentheses refer to items in References at the end of this note.

tive of the causal factors that determine the discrepancy" (7, p. 210).

Often, policy analysts want information about probable changes in the aggregate market response. Such estimates are ordinarily obtained from time series data, quite often with limited sample sizes. Generating the aggregate response from cross-sectional data and then, with an estimate of the adjustment rate, deriving the shortrun response, appears preferable, for at least two reasons, to the procedure suggested by Nerlove for obtaining longrun responses from time series models. First, the equilibrium response can be generated by use of a data base which describes structural change. Changes in the parameters over time can be observed. Second, in most studies, cross-sectional data permit a closer correspondence of the empirical estimation to economic theory.

Methods which permit structural estimation from continuing micro-unit data systems have been developed (*1, 5, 8, 10*). Such methods have been employed less than they should, possibly because of the lack of price and quantity data, computer software, or the physical limits imposed by computer hardware systems.

William T. Boehm
Assistant Professor of Agricultural Economics
Virginia Polytechnic Institute and State University

Joseph Havlicek, Jr.
Professor of Agricultural Economics and Statistics
Virginia Polytechnic Institute and State University

Emerson M. Babb
Professor of Agricultural Economics
Purdue University

REFERENCES

(1) Balestra, P., and M. Nerlove. "Pooling Cross-Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas." *Econometrica*, Vol. 34, No. 3, July 1966, pp. 585-612.

(2) Boehm, W. T., and E. M. Babb. *Household Consumption of Beverage Milk Products* . Purdue Agr. Expt. Sta. Bul. No. 75, West Lafayette, Ind., June 1975.

(3) ___________ *Household Consumption of Storable Manufactured Dairy Products*. Purdue Agr. Expt. Sta. Bul. No. 85, West Lafayette, Ind., June 1975.

(4) ___________ *Household Consumption of Perishable Manufactured Dairy Products: Frozen and Specialty Products*. Purdue Agr. Expt. Sta. Bul. No. 105, West Lafayette, Ind., Sept. 1975.

(5) Fullter, W. A., and G. E. Battese. "Estimation of Linear Models With Cross-Error Structure." *J. Econometrics*, Vol. 2, No. 1, May 1974, pp. 67-78.

(6) George, P. S., and G. A. King. *Consumer Demand for Food Commodities in the United States With Projections for 1980*. Giannini Found. Monog. No. 26, Mar. 1971.

(7) Kuh, E. "The Validity of Cross-Sectionally Estimated Behavior Equations in Time Series Applications," *Econometrica*, Vol. 27, 1959, pp. 197-214.

(8) Nerlove, M. "Distributed Lags and the Estimation of Long-Run Supply and Demand Elasticities: Theoretical Considerations." *J. Farm Econ.*, Vol. XL, May 1958, pp. 301-311.

(9) Rojko, A. S. *The Demand and Price Structure for Dairy Products*. U.S. Dept. Agr. Tech. Bul. No. 1168, May 1957.

(10) Wallace, T. D., and A. Hussain. "The Use of Error Components Models in Combining Cross Section With Time Series Data." *Econometrica*, Vol. 37, No. 1, Jan. 1969, pp. 55-72.

SOME HISTORICAL NOTES ON THE FARM DEFINITION

On August 12, 1975, the Census Bureau and USDA announced that the official definition of a farm would be revised to include only places that sold—or would normally sell—at least $1,000 worth of agricultural goods annually. This change is the latest development in an effort, now underway for over 125 years, to determine what will constitute a farm for statistical purposes. Its enactment provides an opportunity to examine where the definition has come in that time.

The first census of agriculture seems to have used no definition at all. Taken in 1840, it included only 37 questions and dealt exclusively with production, failing to note even the number of farms in the country. Enumerators reported on crops and livestock by districts rather than by individual farms, and for that reason, apparently, officials in Washington felt no need to formulate a farm definition (*6*, pp. 233-34).[1]

The number of agricultural operations was first counted in 1850, the same year that the Federal Government issued its earliest definition of the term "farm." By the newly established standard, a farm became a place of any size producing at least $100 worth of agricultural goods each year. This criterion marked the beginning of a series of definitions whose main features, as summarized by the Census Bureau, are presented in the table.

Generally, the definition since 1850 has been changed for two reasons: to exclude operations too small to be reasonably considered farms; to ensure the *inclusion* of places, such as greenhouses and apiaries, that might not commonly be thought of as farms, despite their significant agricultural production. The 1870 definition, which lasted longer than any other in the country's history, demonstrated both considerations and also revealed a remarkable emphasis on commercial agriculture. In addition, it was the first definition to set a higher production standard for small places than for large, a feature that has characterized nearly all its successors. " 'Farms,' for purposes of the agricultural schedules," it said:

> include all considerable nurseries, orchards, and market gardens . . . which are cultivated

[1] Italicized numbers in parentheses refer to items in References at the end of this note.

Census Bureau summary of farm definitions used in census of agriculture, 1850-1974

Year of census	Acreage limitations	Other criteria
1850, 1860	None	$100 worth of agricultural products produced for home use or sale.
1870, 1880, 1890	3 acres or more	Any agricultural operation.
	Less than 3 acres	$500 worth of agricultural products sold.
1900	None	Agricultural operation requiring continuous services of at least one person.
1910, 1920	3 acres or more	Any agricultural operation.
	Less than 3 acres	$250 worth of agricultural products produced for home use or sale; or constant services of at least one person.
1925, 1930, 1935, 1940	3 acres or more	Any agricultural operation.
	Less than 3 acres	$250 worth of agricultural products produced for home use or sale.
1945	3 acres or more	Agricultural operation consisting of 3 acres or more of cropland or pastureland; or $150 worth of agricultural products produced for home use or sale.
	Less than 3 acres	$250 worth of agricultural products produced for home use or sale.
1950, 1954	3 acres or more	$150 worth of agricultural products produced for home use or sale.
	Less than 3 acres	$150 worth of agricultural products produced for sale.
1959, 1964, 1969	10 acres or more	$50 worth of agricultural products produced for sale.
	Less than 10 acres	$250 worth of agricultural products produced for sale.
1974	None	$1000 worth or more of agricultural products produced for sale.

Source: (*15*, p. 9).

> for pecuniary profit, and employ as much as the labor of two able-bodied workmen during the year. . . . No farm will be reported of less than 3 acres, unless $500 worth of produce has been actually sold off from it during the year. The latter provision will allow the inclusion of many market gardens in the neighborhood of large cities, where, although the area is small, a high state of cultivation is maintained and considerable value produced (*4*, p. 746).

The 1870 standard was stringent. Less than half of all the Nation's farms during the last third of the 19th century produced $500 worth of goods, let alone sold that much. By 1900, officials were concerned about the number of full-time farmers going unreported because of the sales limitation, and the definition devised that year reflected their uneasiness. It held that a farm for census purposes would be any agricultural operation, regardless of acreage or sales, that completely employed at least one person (*4*, p. xiv).

Further modifications followed early in the 20th century. And in the thirties, as the country began to develop a mature agricultural policy, new pressures arose to eliminate very small operations from the census. The argument for a more restrictive definition grew out of a need to handle so-called "average" farm figures, which typically included data from places that were not farms in any meaningful sense. Yet, as the need for revisions in the definition increased, the difficulties of making changes grew accordingly. A major move to break out of the quandary came after World War II with the introduction of the economic classification of farms. Among its attributes, the new system seemed to promise a way to separate commercially insignificant units from the total without redefining them out of existence.

That attack on the problem did not prove sufficient, however, and so, demands for revisions in the farm definition have continued to the present. In 1962, Ray Hurley, head of the Census Bureau's Agricultural Division, declared that none of the classifications tried since 1940 had eliminated the misuse of "average farm figures," based on a number that included "more than a million 'not really' farms." Hurley proposed to alleviate the problem by eliminating from the count all places without annual sales of at least $2,500. Ten years later, a USDA policy study group, The Young Executives Committee, aroused public protest by arguing for a bottom sales figure of $5,000. The Department disclaimed the Young Executives' report as an official document, but it was clear even then that the definition would eventually be made more exclusive (*1*, pp. 619, 621; *2*, p. 4).

The new criterion replaces those formulated in 1959. As the table shows, a farm by the 1959 standard was any operation of 10 acres or more with at least $50 in annual sales, or any place of less than 10 acres that sold a minimum of $250 worth of goods each year. Despite the contrast between the old and new definitions, the latest revision is not a dramatic departure from past practices. But its closest parallels are more than 70 years old. It is the first definition since 1900 to disregard acreage, and therefore it is the first since then not to establish separate requirements for large and small operations. Moreover, it is the only definition since the original 1850 standard that requires all operations, no matter what their physical size, to meet an identical test relating to production if they are to be included in the census. In this respect, the definition has come nearly full circle after 125 years.

Unlike its 1850 predecessor, the 1975 revision relies on value of sales rather than a simple value of production figure. The use of sales has been a continuous part of the definition only since 1950, but it first appeared as a criterion in 1870. Similarly, the new cutoff ($1,000 in sales) has something of a 19th century counterpart in the $500 sales requirement that small operations had to meet to be included in the censuses of 1870, 1880, and 1890. That figure was easily as rigorous in the last 20 years of the previous century as the $1,000 stipulation is today.

Thus, the 1975 revision follows well-established precedents. As an effort to separate farm from nonfarm enterprises, it continues an approach rooted in the last century. More than 90 years ago, Francis Walker, then Superintendent of the Census, noted that "In reaching out to cover the potato patch, tilled at odd hours by the factory hand, or the vegetable garden of the village shopkeeper, lawyer or blacksmith, the census would lose far more than it gained" (*3*, p. viii). Today's census still seeks to distinguish the potato patch and the vegetable garden from the farm—and it still does so in a way that would have been familiar to Francis Walker.

David E. Brewster
Agricultural Historian
National Economic Analysis Division

REFERENCES

(1) Hurley, Ray. "Census Concepts: Past, Present, and Future." *J. Farm Econ.*, Vol. 44, No. 2, May 1962, pp. 616-21.

(2) "New Directions for U.S. Agricultural Policy: Report of the U.S. Department of Agriculture's Young Executives Committee," 1972. Photocopy in History Group Files, Econ. Res. Serv., U.S. Dept. Agr.

(3) U.S. Census Office. *Tenth Census: Report on Agriculture*. 1883.

(4) ________ *Twelfth Census of the United States*. Vol. 5, *Agriculture*, Pt. 1, *Farms, Live Stock, and Animal Products*. 1902.

(5) U.S. Congress, House Committee on Agriculture. *Redefinition of the Term "Farm," Hearings before the Subcommittee on Family Farms and Rural Development*. 94th Cong., 1st sess., Nov. 7 and 12, 1975.

(6) Wright, Carroll D. *The History and Growth of the United States Census*. Washington, 1900.

U.S. GOVERNMENT PRINTING OFFICE : 1977 O—228-018

Suggestions for Submitting Manuscripts for
Agricultural Economics Research

Contributors can expedite reviewing and printing of their papers by doing these things:

1. **SOURCE.** Indicate in a memorandum how the material submitted is related to the economic research program of the U.S. Department of Agriculture and its cooperating agencies. State your own connection with the program.
2. **CLEARANCE.** Obtain any approval required in your own agency or institution before sending your manuscript to one of the editors of *Agricultural Economics Research*. Attach a copy of such approval to the manuscript.
3. **ABSTRACT.** Include an abstract and at least three keywords when you submit your article. The abstract should not exceed 100 words.
4. **NUMBER OF COPIES.** Submit three good copies.
5. **TYPING.** Double space everything, including abstract and footnotes.
6. **FOOTNOTES.** Number consecutively throughout the paper.
7. **REFERENCES.** Check all references carefully for accuracy and completeness.
8. **CHARTS AND OTHER ARTWORK.** Use charts sparingly for best effect. Keep design as simple as possible to improve communication. Submit all artwork in draft rather than final form, accompanied by neatly prepared pages with essential data for replotting. Complex or detailed charts and other artwork are usually best suited to full page or 2 page treatment (final image size will be 6-5/8" x 4-3/8"). Simpler charts should be designed to fit half page (final image size of 6-5/8" x 4-3/8") or quarter page (final image size of 3-3/8" x 4-3/8").
9. **FINAL TYPING.** Two good copies, double spaced, will be required of final copies of edited and revised manuscripts accepted for publication.

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C. 20250

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF
AGRICULTURE

FIRST CLASS
AGR 101

U.S.MAIL

AGRICULTURAL ECONOMICS
RESEARCH

The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director, Office of Management and Budget, through February 28, 1980.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. $1 a single copy, $3.85 a year domestic, $4.85 foreign.